# SOURCES OF REFRACTORY RAW MATERIALS AND REFRACTORIES MARKETS IN SOUTH CENTRAL UNITED STATES

By Howard E. Rollman and Harvard Eng

* * * * * * * * * * information circular 7950

UNITED STATES DEPARTMENT OF THE INTERIOR
Fred A. Seaton, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

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# SOURCES OF REFRACTORY RAW MATERIALS AND REFRACTORIES MARKETS IN SOUTH CENTRAL UNITED STATES[1/]

by

Howard E. Rollman[2/] and Harvard Eng[3/]

## SUMMARY AND CONCLUSION

South Central United States, an area including Arkansas, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, and Texas, is a net exporter of refractories. Nearly $45 million of these materials was shipped in 1954 from plants in the area, compared with area consumption of $18.5 million. About 88 percent of all refractories production is concentrated in Missouri. The prevalent consumption pattern, however, is one of localized shortages. For example, although Texas uses more than half of the refractories consumed in the South Central United States, production of refractories in Texas is relatively small. Also, the apparent self-sufficiency of the area is in terms of value produced rather than in terms of products consumed. Nearly all of the $6,425,000 nonclay refractories consumed in the area were shipped from other States. Local resources possibly could be developed for making refractories to serve markets that currently are being supplied from outside the area. Since other industries are growing rapidly in the area, the market for refractories is expected to continue to grow--more rapidly than the national market.

The Missouri refractories industry is economically important nationally. Nearly one-fourth of the clay refractories produced in the United States are made in Missouri. Moreover, Missouri produces most of the higher grade clay refractories, about 62 percent of the high-alumina refractories, and 85 percent of the superduty refractories. The competitive position of the Missouri refractories industry is strong. The national market for clay refractories and the market in the South Central United States are expected to continue to grow. The ratio of net income to the value of refractories shipped in Missouri is larger than the national average.

Plastic, flint, burley, and diaspore clays occur in Missouri. The supply of plastic clays appears adequate for predicted needs. The need for diaspore

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clay has been alleviated by using bauxite from British Guiana. In maintaining production of higher quality refractories the major factor is development of the potential flint-clay resources of Missouri. The supply of flint clays is diminishing, and the discovery rate is declining. Annual demand for refractory clays in Missouri by 1975 is estimated at 2.6 million tons. Demand for fire-clay refractories is expected to increase only half as fast as the total refractory demand. Demand for Missouri fire clays, however, is estimated to be growing at 2.4 percent per year, compared with a rate of 2.8 percent for all refractories. Missouri refractory clay is expected to reach 32 percent of the national total by 1975. The increased demand for high-grade refractories and for raising the quality of lower grade refractories will continue to drain already diminishing supplies of superduty clays. Refractory raw materials potentially available are unusable because of contained impurities; therefore, the long-term supply of high-grade clays will depend on research.

## INTRODUCTION

This study is an economic evaluation of the supply and markets for refractory raw materials and refractories in the South Central United States. The study is a functional appraisal of resources--an analysis of raw materials functioning in their economic environment. It is not a resource study in the usual sense of a catalog of raw materials physically available. Present and potential supplies of raw materials are discussed only so far as they may be related to present and potential market demands.

The three primary objectives of the study are:

1. To compile statistical data on markets for refractories and refractory materials.

2. To provide essential economic information needed for government and business planning of the effective development and conservation of refractory raw materials.

3. To analyze the economic forces affecting the long-range resource position of the area.

Essentially, the problem is to establish a supply-demand relationship. Present and projected needs of the South Central United States and the Nation are correlated with current and potential supplies of refractories and refractory raw materials. The determination of need is an economic problem. Finding and developing refractory minerals is a task for the geologist, the mining engineer, the ceramic engineer, and the manufacturer. Their work helps to determine economic availability.

This report describes how the refractories needs of the South Central United States are met and how refractories producers in the area meet requirements of consumers outside the area.

Market statistics were compiled from three primary sources: (1) Major refractories producers who ship within or into the South Central United

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States; (2) a sample of major consumers of refractories in the area; (3) an analysis of shipments of refractory materials based on Carload Waybill Statistics of the Interstate Commerce Commission (ICC).

Refractories manufacturers supplying figures on shipments into the area produced about 50 percent of the value of refractories made in the United States. This group, representing several of the largest manufacturers in the industry, produced all major categories of domestically produced refractories.

Additional market information was obtained from a group of consumers chosen on the basis of industry type and size of operation. These consumers furnished information on sources of supplies, purchasing practices, and changes in refractories usage. By selecting consumers in various parts of the geographical area studied, it was possible to confirm shipments of refractory products from manufacturing centers outside the South Central United States.

There is a scarcity of data on the origination and destination of shipments of refractories. ICC compiles annual statistics of shipments of refractories from States of origination to State of destination. These statistics are based upon a 1-percent sample of carloads shipped. To compensate for quantitative and geographic errors that will appear in any given year, because of size of the sample, the statistics compiled from ICC data were based on available data for 8 years. The analysis of Carload Waybill Statistics were used both for quantitatively checking on shipments and for determining points of origination of shipments into the area.

Freight rates were obtained from traffic managers of railroads that have lines servicing refractories manufacturing centers. Intrastate truck and rail rates on bulk clay were obtained from the State regulatory bodies.

Information on occurrences and distribution of refractory materials was obtained from State geologists, mining engineers and geologists of the refractories companies in the area, and from a search of published and unpublished geologic literature. Other technical advice was obtained from production and research personnel of the refractories companies. Certain technological factors that have economic significance also were considered.

Selection of 1954 for the sample survey year was unfortunate because, nationwise, it was a particularly low period for shipments of refractories. Consumption figures, therefore, for the Southwest are not necessarily a typical segment of total national consumption, and the period should be viewed critically as possibly one in which the normal supply-demand forces were not operating.

## ACKNOWLEDGMENTS

The cooperation and assistance of A. P. Green Fire Brick Co., General Refractories Co., Harbison-Walker Refractories Co., Kaiser Aluminum & Chemical Corp., Laclede Christy Division of H. K. Porter Co., Inc., Mexico Refractories Co., North American Refractories Co., Valley Dolomite Corp., Walsh Refractories Corp., Wellsville Fire Brick Co., and the State geologists of

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Arkansas, Kansas, Louisiana, Mississippi, Missouri, Oklahoma, and Texas are hereby gratefully acknowledged.

## OCCURRENCE AND DISTRIBUTION OF REFRACTORY MATERIALS

Refractory materials produced in this area include high-alumina clays, tabular alumina, novaculite, refractory dolomite, seawater magnesia, and all types of fire clays. From these raw materials, silica refractories, dead-burned dolomite, fire clay, and high-alumina refractories are manufactured in the area. Magnesia is scheduled for use in manufacturing basic refractories in 1959.

The area studied is shown in figure 1. Raw materials for refractories are produced in only four of the seven States shown. Missouri is by far the

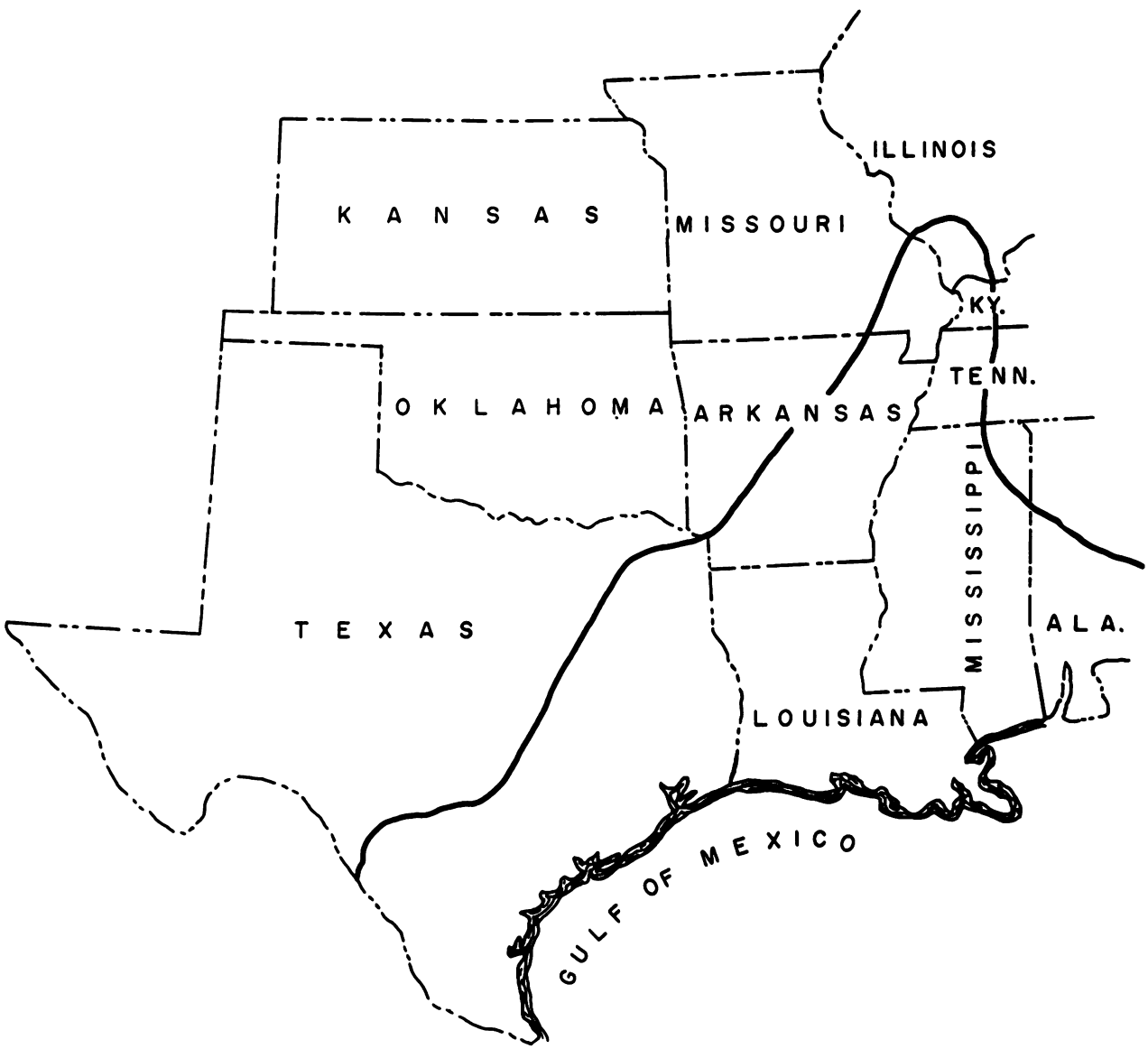


FIGURE 1. - Outline of Eocene Sediments in South Central United States.

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largest producer of raw materials and refractories in the South Central United States. Compared with Missouri, the other producing States--Texas, Arkansas, and Mississippi--are minor producers.

## Arkansas

Refractory raw materials produced in Arkansas include novaculite, tabular alumina, kaolinitic clays, and fire clays (fig. 2).

Novaculite, the raw material for the silica brick produced in the area, is quarried in Hot Spring County, Ark. The material also occurs in Garland, Montgomery, Pulaski, and Saline Counties. Outcrops occur as parallel ridges

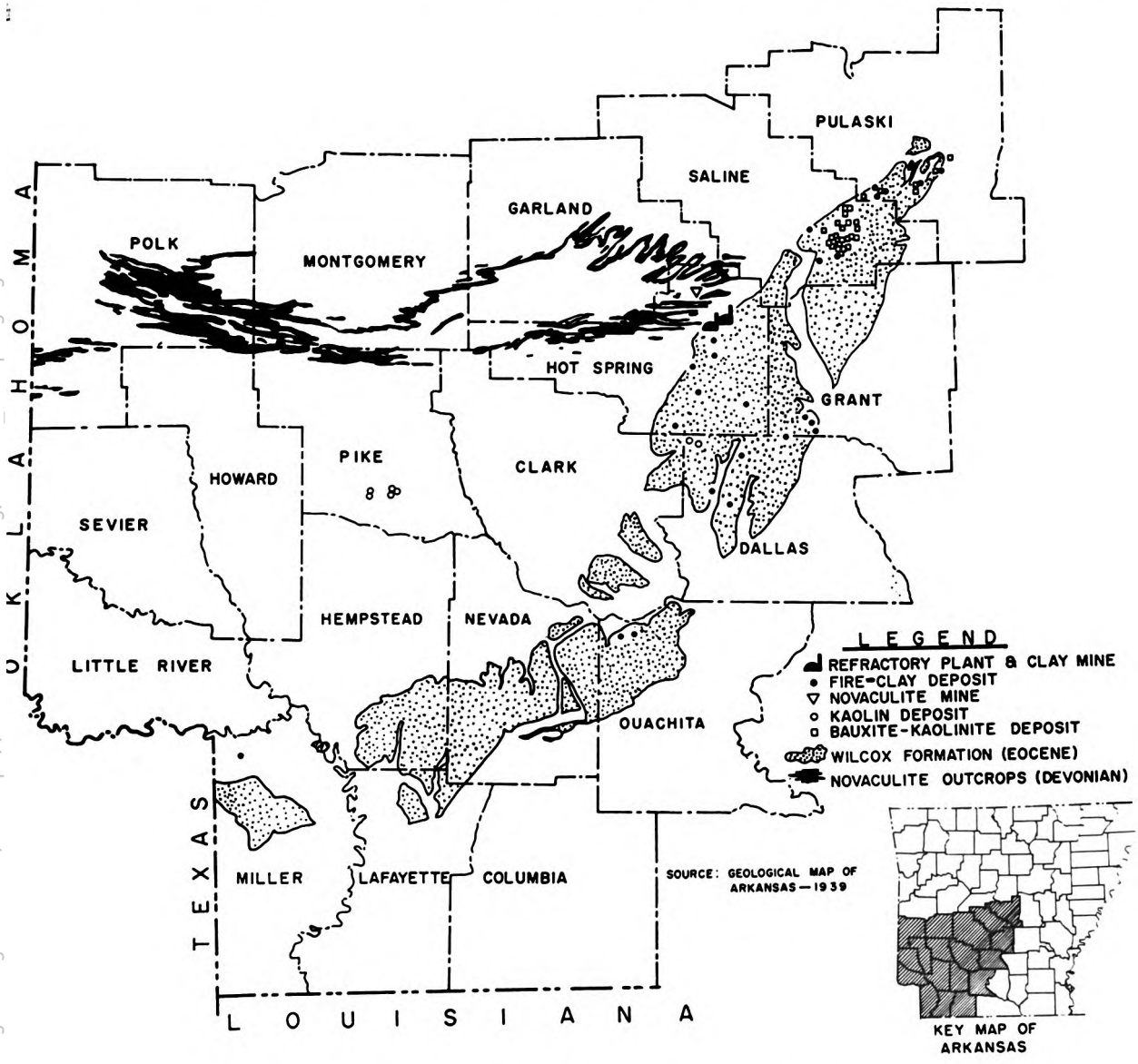


FIGURE 2. - Refractory Resource Map of Arkansas.

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from Montgomery County to Pulaski County. The novaculite is more than 99 percent pure silica, and the product made from it is reported to be exceptionally high grade.

Tabular alumina is produced in small quantities by the aluminum industry in Arkansas and is used to increase the alumina content of the very high alumina refractories (80-99 percent alumina).

Two companies are utilizing clays of the Wilcox formation (Eocene) for firebrick at Malvern and Perla, Ark. Generally, sediments of sand, lignite, and clay lie in a discontinuous band following closely the perimeter of the Mississippi Embayment (18)[4/]. Exposures are found in 10 counties in the southwest and central parts of the State. The formation is reportedly 600 to 650 feet thick. Clay lentils that occur in the formation range from a few inches to 30 feet in thickness and up to 40 acres in areal extent. These lentils contain little lamination and are composed mainly of kaolinite and quartz with iron and alkalies as impurities. Other impurities are lignite and titania, but these do not impair refractory properties.

Two areas containing bauxite-kaolinite deposits lie approximately 14 miles apart in Saline and Pulaski Counties. These areas comprise the bauxite-kaolinite district of Arkansas and are closely associated with the bauxite deposits mined for aluminum production. The areas, probably formed as residual deposits in early Wilcox time, are considered part of the Wilcox formation (7).

Although the residual clays of the bauxite-kaolinite district are potential sources of refractory materials, their refractory properties have received only cursory examination. Some of these kaolinitic clay beds may be of sufficient refractory quality, but they will require processing before utilization.

Clays lie above and below the bauxite. Those clays lying over the bauxite were stripped with the overburden and wasted. Clays lying under the bauxite were covered during panel mining after the bauxite was mined. Recently, however, some of the clays above the bauxite have been mined and stockpiled. Sizable tonnages of kaolinitic clays have been calcined and shipped to Missouri as a substitute for flint clays in refractories.

## Kansas

No commercial supplies of refractory raw materials are known in Kansas. A test of ball clays from the Dakota formation in central Kansas demonstrated that the clays could be upgraded to high-grade refractory material, but this beneficiation is not economic now.

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4/ Underlined numbers in parentheses refer to items in the bibliography at the end of this report. Pages cited refer to the item and not to this publication.

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According to the Kansas State Geological Survey, a report is being prepared on a laboratory investigation of refractory clays and silts of the Dakota formation. It is reported that the present clay is satisfactory, without beneficiation, for the production of semisilica refractories.

## Louisiana

No economic supplies of refractory raw materials are known to exist in Louisiana.

## Mississippi

Fire clays are known to exist in northern Mississippi. Ball clays for use as refractory bond clays are mined and processed near Crenshaw.

High-alumina clays, bauxite, and kaolinitic clays associated with the bauxite are unevaluated possible refractory raw materials found in the State. Some fire clays in Mississippi are suitable for manufacturing high-heat-duty firebrick.

In 1957 refractory ball clay was produced from deposits in Zilpha formation (Claiborne) near Crenshaw, Panola County, and at a small mine near Sledge in Quitman County. Extensive deposits also exist in Tallahatchie County, but there is no commercial exploitation of refractory ball clays now. Large quantities of ball clays from Tallahatchie County were mined during World War I for use in glass pots and in metallurgical refractories. The ball clays of the Zilpha formation compare favorably with German bond clays.

## Missouri

### Fire Clays

Missouri contains probably the largest reserves of quality plastic and semiplastic fire clay in the United States (30, p. 3). The Cheltenham formation, from which the Missouri fire clays are derived, lies roughly in a triangle with its corners near St. Louis, in northwestern Audrain County, and in southwestern Crawford County. This area has been divided into two districts--the Northern Fire-Clay District, north of the Missouri River, and the Southern Fire-Clay District, south of the River. Figure 3 shows the location of pits and refractories plants operating in 1957.

The clays of the Cheltenham formation range in thickness from a few inches to 50 feet. The clays are thicker in the north, and the ceramic properties change from north to south. Clays with higher alumina content occur in the south and grade toward the higher silica clays in the north. Flint clays, however, occur in both districts. Generally, the higher quality clays are found toward the bottoms of the rolls or horsebacks and in sinkholes.

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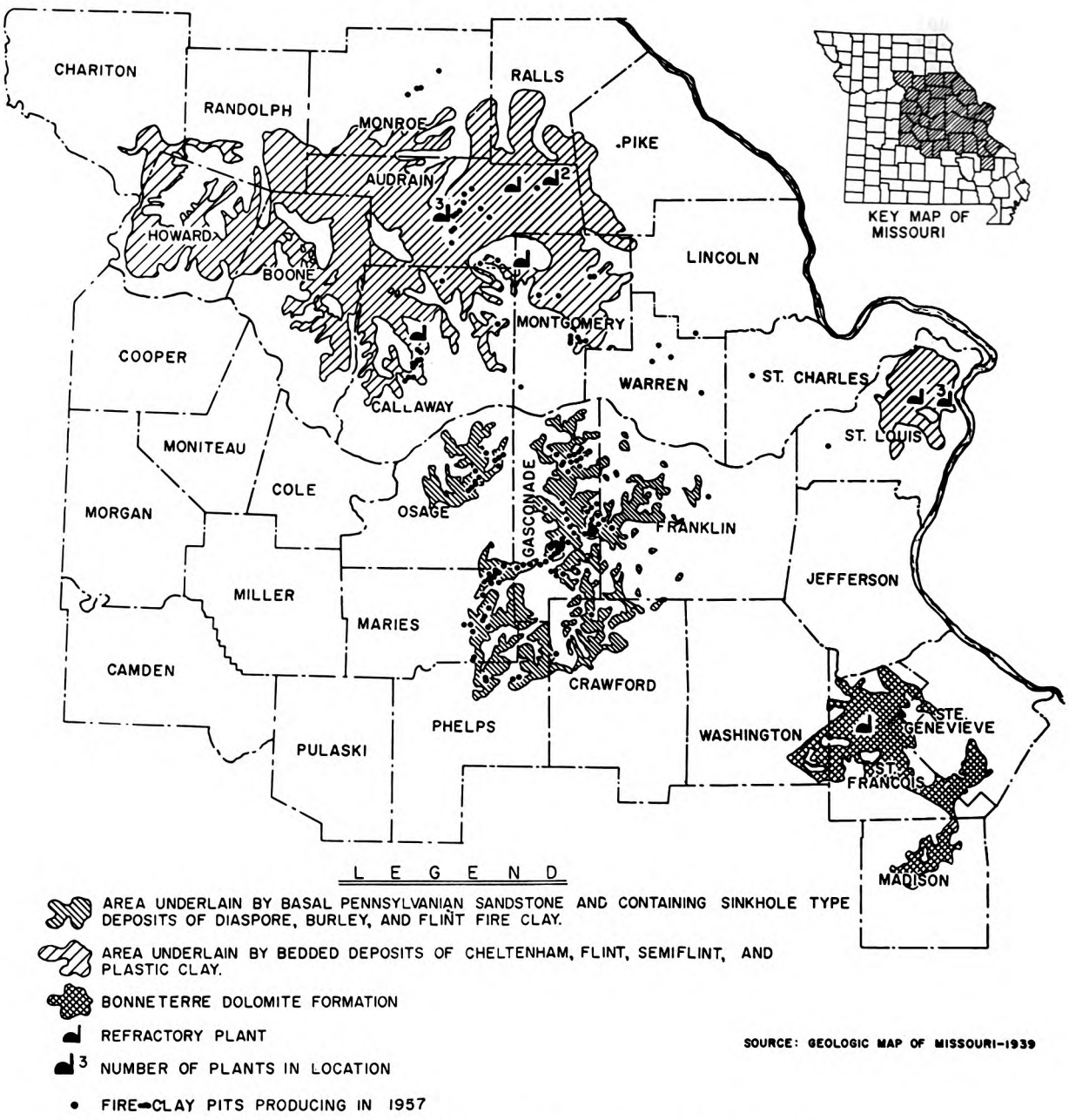


FIGURE 3. - Refractory Resource Map of Missouri.

## Northern Fire-Clay District

In the Northern District the Cheltenham formation lies in most of Audrain, northern Callaway, and northwestern Montgomery Counties. It contains refractory clays varying from semiplastic to flint.

## Southern Fire-Clay District

The Southern District covers all or parts of the following counties: Crawford, Gasconade, Maries, Osage, Phelps, and Franklin. Refractory clays

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of the Southern District are mainly flint, burley, and diaspore. Individual deposits usually vary from semiflint through burley to diaspore. Deposits occur in isolated sinkholes ranging from a few feet to about 100 yards in diameter and from a few feet to 200 feet in depth.

### Other Refractory Materials

Dead-burned dolomite is produced near Bonne Terre, Mo., and used as a refractory by the steel industry in open-hearth furnaces. The Bonneterre dolomite locally is highly pure and uniform in chemical composition. The formation is quite extensive and will provide adequate dolomite reserves for many years.

Kaolin and ball clays occur in southeastern Missouri.

## Oklahoma

The extension of the novaculite formation from Arkansas into southeastern Oklahoma presents the best potential refractory material source in the State. The material, called "Ouachita Stone," is less dense than Arkansas novaculite and is of exceptional purity. Utilization will depend on results of testing and on growth of market for this material in the area.

## Texas

Refractory materials in Texas include fire clays, kaolin, magnesite, magnesia, and novaculite. Figure 4 shows potential sources of refractory materials.

### Fire Clays

The Wilcox group (Eocene) extends through Texas in a southwest-northeasterly direction (fig. 4). The group generally is composed of nonmarine sediments, although on the south flank of the Sabine uplift brackish water. sediments, which do not include as many highly refractory clays, are present. The Wilcox formation is a heterogeneous series of variable thicknesses composed of sand, lignite lenses, lignitic clays, and clays (40, p. 573).

Ball clay occurs in the Troup District in Smith and Rockdale Counties. This clay, found in the upper 100 feet of the Rockdale member, ranges in thickness up to 12 feet. It has a uniform color--light-bluish gray when fresh and white when exposed to sunlight (58, p. 14).

Near Athens, Henderson County, the upper Rockdale member of the Wilcox group contains fire clay associated with lignites. The clay bed ranges from 2 to 12 feet in thickness and rests upon a bed of white, even-grained sand that is 5 or more feet thick. Lenticular clay beds extend over an area of approximately 2 square miles.

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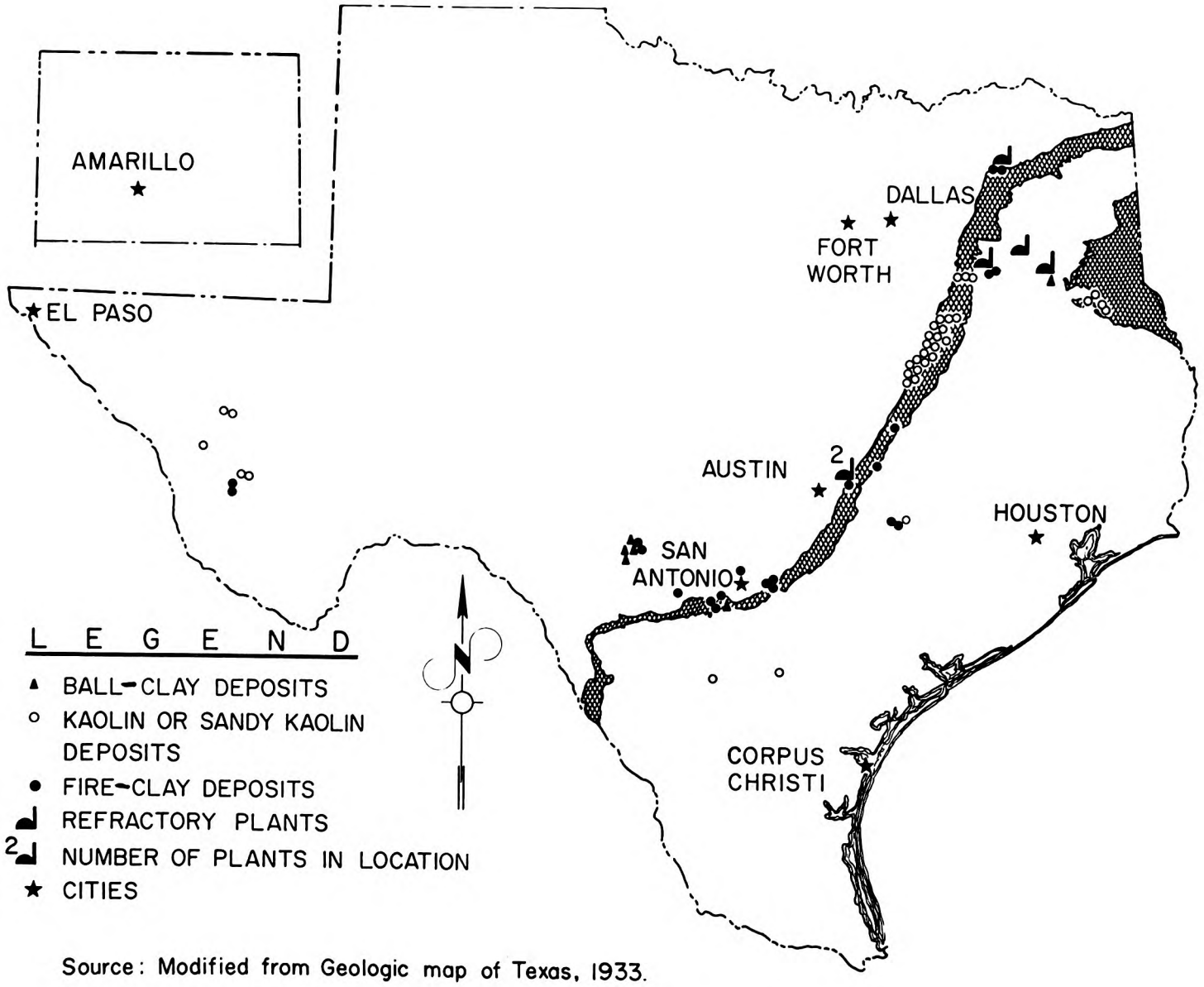


Source: Modified from Geologic map of Texas, 1933.

FIGURE 4. - Refractory Resource Map of Texas.

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Clays are being produced in four areas at Troup and Tyler, Smith County; Athens, Henderson County; and Sulphur Springs, Hopkins County, in northeastern Texas; and Elgin, Bastrop County in central Texas.

Refractory-clay deposits have been found and tested in other localities in the Wilcox group. These clays, however, have not been used to produce refractories. Exploration has been on a small scale.

The Wilcox formation with its lenticular beds of clay probably has many deposits of high-grade clays in areas other than the northeastern and central areas of Texas. A systematic program for exploration may locate more of these lenticular deposits.

## Kaolin

Two deposits of kaolin occur in Texas--one in Jeff Davis County, 16 miles north from Fort Davis on Valentine Road, and the other in Real County, 5 miles northwest of Leakey.

The Jeff Davis County deposit contains high-quality kaolin (5, 50).

The Leakey kaolin deposit of Real County occurs in cavities resembling sinkholes. The north cave contains kaolin, whereas the southern cave contains sandy fire clay. The deposit contains an estimated 140,000 tons of kaolin and several hundred thousand tons of sandy fire clays. To date these clays have not been utilized for refractories because of excessive distance to established plants and markets. The area has been explored extensively, and the clay found to be of high quality. These clays may eventually be utilized for other ceramic pruposes.

Sand-kaolin deposits occur in the Wilcox formation of northeastern central Texas (39). These siliceous kaolins might be beneficiated to refractory quality.

## Novaculite

Novaculite occurs in the Caballos formation (Devonian) and crops out in ridges in the Marathon area of Brewster County. Exploration and testing may prove this novaculite to be of refractory quality (53, p. 374).

## Dolomite

High magnesium dolomite is distributed widely in Texas, except in the coastal plain area and in the greater part of the High Plains of northwest Texas. Dolomite occurs in rocks ranging from pre-Cambrian to Cretaceous in age. Dolomite is mined from large deposits of the Ellenburger formation (Ordovician) in Burnet County. International Mineral and Chemical Corp., Austin, Tex., and Mathieson Alkali Works, Lake Charles, La., have used dolomite for the recovery of magnesia and magnesium compounds (53, p. 368).

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## FIRE-CLAY INDUSTRY

### Missouri

#### Classification of Clays

Fire clays in Missouri vary widely in chemical and physical properties. They range from a soft plastic clay to a very hard clay nearly without plasticity. They also vary in particle size, density, shrinkage, vitrification range, porosity, strength, and other characteristics.

High-grade flint fire clays have an alumina content of about 40 percent and a pyrometric cone equivalent (P.C.E.) of 33 to 34. Missouri flint clays are characterized by lack of plasticity and by conchoidal fracture. They are smooth, fine-grained, and have suitable fired density and physical structure. The maximum fired shrinkage, moderately high and somewhat variable, can be achieved at a relatively low temperature.

Burley clays are so-named because they contain burls with a high alumina content. They have about 55 percent alumina and an approximate P.C.E. of 34.

Burley-flint fire clays are classified between burley and flint clays. They are difficult to use because of reheat shrinkage.

The major commercial deposits of diaspore in the United States are in Missouri. First-quality diaspore clays have an alumina content of over 68 percent and a P.C.E. of 36 or higher. Diaspore is coarse textured and high in alumina.

Plastic clays are characterized by their moldability and capacity to bond nonplastic materials.

Semiflint and semiplastic fire clays vary in refractoriness, plasticity, and bonding strength. Drying and firing shrinkages usually are fairly high. The clays are so-named because, although they are neither true flint nor plastic clays, they have the general characteristics of the type for which they are named.

#### Reserves

No effort was made to obtain reserve figures from each company and to relate these reserve figures to predicted demand. However, according to verbal statements obtained from Missouri refractories companies, Missouri reserves of fire clays suitable for manufacturing refractories of lower than superduty grade are sufficient for any anticipated national demand. Plastic and semiflint clays of the Northern Fire Clay District are extensive and appear adequate to meet high-heat duty requirements at anticipated levels of demand for 50 years.

The supply of Missouri flint clay necessary for producing superduty refractories is increasingly difficult to maintain. The decrease in the supply

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of superduty clays could limit the capacity of the area to satisfy the long-term demand. Because Missouri provides about 85 percent of the national-market demand, developing additional reserves, finding suitable substitutes, or upgrading low-grade clays by beneficiation are essential to assure long-term raw material supplies. The declining discovery rate and rising exploration costs emphasize the need for an intensified program of research and investigation.

Substituting bauxite for diaspore has augmented the supply of raw materials for high-alumina refractories manufacture. Although two-thirds of the national requirements of high-alumina refractories are still supplied by plants in Missouri, substitution of British Guiana bauxite may change this pattern. Because of the high cost of shipping bauxite from eastern ports to Missouri and the subsequent reshipment of high-alumina refractories to eastern markets, future production facilities for these refractories may be more widely dispersed geographically.

## Exploration

The discovery and production of high-quality clays in Missouri are becoming increasingly more costly than would result from the rising labor-wage scale alone. The principal factors contributing to higher costs are a declining discovery rate and increasing ratio of overburden to recoverable clay. Deposits now are being explored for the second, third, and even fourth times. As outcrops became scarce, exploratory drilling costs increased. More costly modern drilling equipment is needed to locate deeper deposits, and scientific methods and trained personnel are required to find the clays. In addition, the demand for raw materials has grown markedly in recent years. Consequently, the major refractories companies now do most of the exploration for clay.

Although there is more exploratory activity for clays than ever before, there are extended periods when discoveries lag. Some deposits explored in the past with auger and churn drills now are being prospected with core drills, which provide better samples; and many deposits, previously rejected, are being acquired for present or future exploitation.

## Mining Practices

### Methods

Most of the clay produced during the early years in the Northern Fire-Clay District of Missouri was mined underground by room and single-entry methods. Shaft mining continued until as late as 1948. Underground mining was hazardous and costly because the roof often was unconsolidated glacial drift and loess. Roof subsidence necessitated frequent retimbering in small rooms. Often the clay was not mined completely because it was necessary to leave the upper part of the clay bed for roof support. Sometimes undesirable clay had to be mined with the plastic or flint clay and then sorted at the surface. Tunneling through the chert rolls to reach the clay was costly.

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Development of large efficient earthmoving equipment and the rise in underground mining costs led to the nearly exclusive use of open-pit mining methods in Missouri by 1940.

According to the chief mining engineers of two of the largest companies operating in the State, as much as 85 feet of overburden has been removed from pits in the Mexico area of the Northern Fire-Clay District. For pits presently in operation, 50 to 65 feet of overburden might be regarded as economic limits. An average ratio of overburden to clay is between 3.5:1 and 4.5:1 in newly-opened pits. In a single pit clay thickness will vary from 3 to 40 feet and average 15 feet.

In the plastic-flint clay area around Fulton, ratios of 1:1 to 2:1 are typical. Twenty feet of overburden is typical in the area. Near Wright City, the overburden ranges from a few feet to 20 feet. Overburden-to-clay ratios of less than 1:1 are common. These are sinkhole deposits. In the Southern Fire-Clay District, overburden-to-clay ratios usually are much less than 1:1; sometimes the overburden is less than 10 percent of the volume removed from the sinkhole. Ten to twelve feet of overburden is regarded as deep.

Development drilling, at intervals of 25 feet with subsequent analysis of samples, enables engineers to mine selectively. Mining is done with large power shovels, and the clays are loaded into trucks. Selective mining has replaced hand sorting. Figures 5 and 6 illustrate the changes wrought by the use of large-scale equipment in open-pit clay mining. The contrast represents changes in mining practices in less than 30 years. Both mines illustrated were in the immediate vicinity of Mexico, Mo.

In the Southern Fire-Clay District, where the clays occur in relatively small pockets rather than in seams, mining is on a smaller scale, and smaller-scale equipment is used. In pits where burley and diaspore clays occur, hand soring is required. Power-drawn scrapers are employed extensively to remove the overburden. After the face is drilled and blasted, either power shovels or dragline excavators are used to load the clay into trucks.

## Contractors

A large part of the clay mined in Missouri is produced by contractors from leases held by the major refractory producers. Before World War II much of the clay used for refractories was obtained on the open market from independent sellers and producers of clays. The independent seller has nearly disappeared, primarily for two reasons. First, the refractories companies now require greater control over mining practices and selection of clays mined. This is particularly needed to control the quality of clays used to manufacture high-grade refractories. Second, in 1951 the tax depletion allowance on fire clay used for refractories was raised to 15 percent. To obtain this tax advantage, refractories companies must own the leases from which production is taken. Depletion allowance permits recovery of exploration costs. Management control problems of producing clays over a broad geographical area apparently are reduced under the contractor system.

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## Stockpiling

In recent years there has been a trend toward stockpiling a larger proportion of the clays at the pits where mined, principally to reduce the amount of money in "freight" inventory if clays are shipped a considerable distance and stockpiled at the plant. Stockpiling at the pit, however, requires an additional loading expense, which averages 30 cents a ton. To permit proper blending of materials to control specifications of each type of refractory, producers store clays obtained from various pits in separate stockpiles insofar as practicable.

## Mining Costs

The total cost of clay delivered at the plant will vary considerably according to the circumstances at individual mines. Among the variables are depth of overburden, ratio of overburden to clay, weather conditions prevailing during productive periods, amount of road that must be maintained, and size of the deposit. In the Northern Fire-Clay District in the Mexico-Vandalia area, the clay occurs in extended seams rather than in sinkholes. This permits much more economical mining. Once the overburden above the seam is removed and roads are built, the mine can be operated effectively with large-scale mining equipment.

In the Southern Fire-Clay District, although the ratio of overburden to clay has been increasing, the overburden is still low enough to favor open-pit over underground mining. In this district, however, the deposits are smaller and more scattered than in the Northern Fire Clay District. Because of rapid depletion, the operator is compelled to move his equipment frequently. Smaller pits, moreover, cannot be mined by large-scale methods.

In 1957 stripping costs in both the Northern and Southern Fire Clay Districts were between 20 and 30 cents per cubic yard. In the Southern Fire Clay District, drilling and blasting costs for clay were between 5 and 10 cents per ton produced. For mining and loading plastic and flint clays, the cost ranged between 40 and 75 cents per ton. Hand sorting the burley and diaspore clays was estimated to range from $3 to $5 per ton.

Royalties paid to property owners in Missouri vary according to the type and quality of clay produced, as well as to certain other economic considerations. In 1957 the general schedule of royalties being paid for various types of clays was:

TABLE 1. - Schedule of royalty payments in Missouri, by type of clay

| Type of clay | Royalty per short ton |
|---|---|
| Plastic and semiflint (Mexico)..... | $0.10 |
| Plastic and semiflint (New Florence)..... | .25 |
| Flint (Southern Fire Clay District)..... | .25 |
| Burley..... | 1.00 |
| Diaspore..... | 2.50-3.00 |

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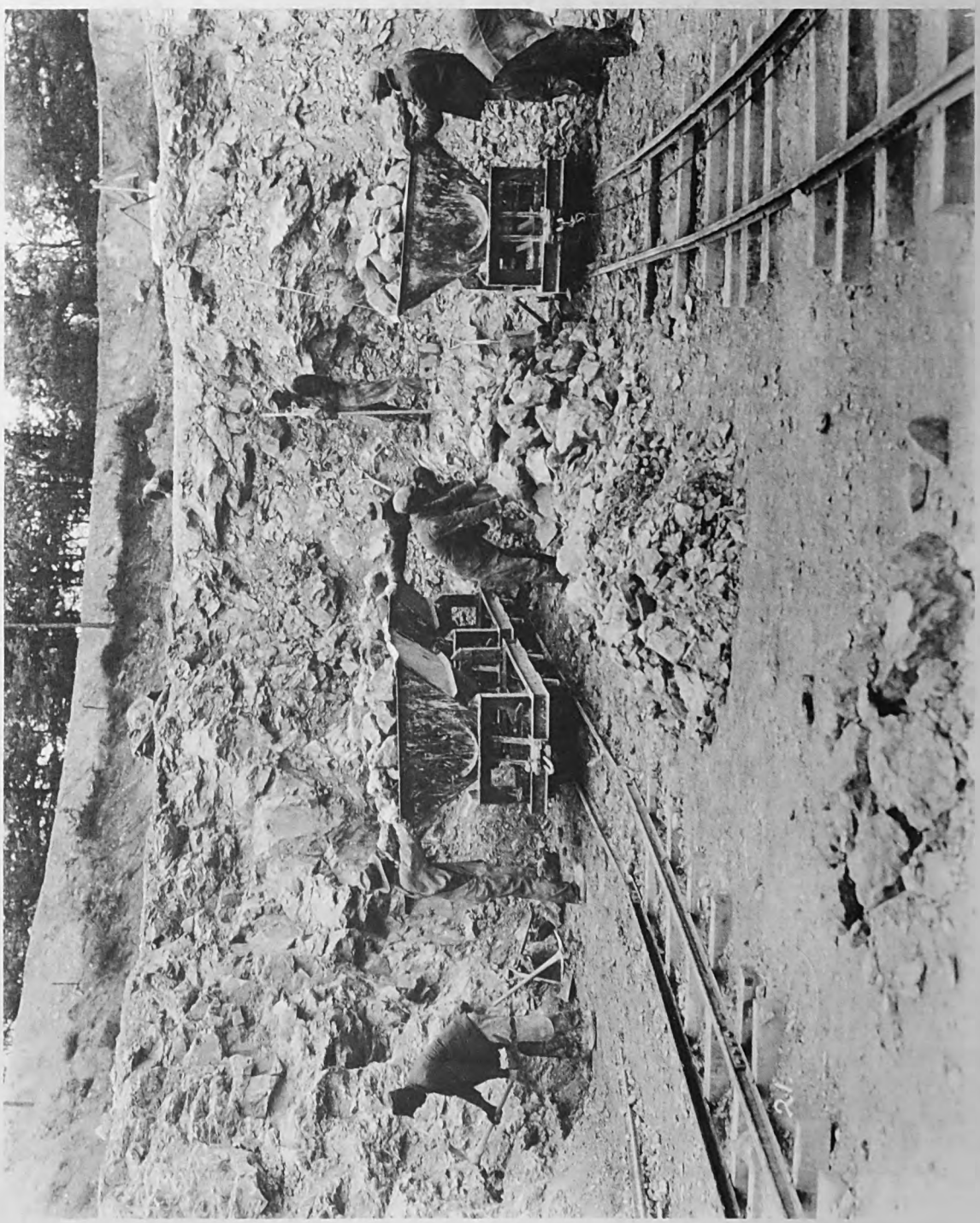

FIGURE 5. - Mining Clay for Firebrick About 1930. Much of the Work Was Done by Hand.

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FIGURE 6. - Overburden Removal at Hook-Leeder Mine, 6 Miles Northeast of Mexico, Mo. The Semiflint Clay Deposit Is 12 to 14 Feet Deep, Under 45 Feet of Overburden.



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Exploration costs are an important factor in the rising cost of production. According to verbal opinions of company geologists, mining engineers, and others engaged in clay mining, an overall exploration cost of 50 cents per ton may be considered reasonable. The cost of prospecting and testing samples is estimated to range from 50 cents a ton for plastic and semiflint clays to $1.50 for high-quality flint clays. Some operators have reported exploration costs (for a given year) as high as $1.50 per ton of clay proved, not including the testing costs. One operator reported that exploration costs of $1.25 a ton of flint clays might well be conservative. Since deposits being mined are smaller and the ratio of overburden to clay is increasing, exploration and mining costs will continue to advance. This is particularly true for flint clays.

Exploratory drilling costs range from $1.00 to $3.25 a foot. Many contracts, however, are made in the Southern Fire-Clay District at $1.00 a foot.

Clay producers in Missouri pay 2 mills per ton as tax for examinations by the State mine inspectors.

In the Southern Fire-Clay District where, in the past, exploration crews frequently uncovered deposits of high-quality flint clays of 50,000 tons and more, deposits now are being mined that yield only between 1,500 and 3,000 tons. A 10,000-ton deposit of high-quality flint clays now is regarded as a large deposit.

Table 2 is a summary of data on the Missouri and U.S. fire-clay industry for 1954.

## Productivity

In a group of 142 open-pit mines operating in the period 1941-45, productivity was 1.09 tons per man-hour (table 3). This is double the productivity figure of underground mines then operating. Consequently, the competitive disadvantage of underground mining resulted in closing all such mines in Missouri.

In a group of 11 of the last underground mines operating in the State in the early 1940's, productivity for an output of 838,000 tons was 0.56 tons of clay per man-hour. These mines were in Audrain, Callaway, Montgomery, and St. Louis Counties. Underground mines operated as late as 1947 in Audrain County and as late as 1948 in Callaway County.

An analysis of 164 mines operating in Missouri between 1951 and 1955 showed an overall productivity figure of 2.77 short tons of clay per man-hour of mine-production workers (table 3). The sample includes mines operating in one or more of the years 1951 through 1955. Some mines were depleted in a single year; some operated for a longer period; and others operated throughout the whole period. The productivity figure was obtained from a cross section of mines with various operating conditions. Data for all operating mines were not available.

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TABLE 2. - Comparative detailed statistics for the fire-clay industry in Missouri and the United States, 1954[1/ 2/]

| Item | Missouri | United States |
|---|---|---|
| Number of operating companies | 45 | 180 |
| Number of establishments | 49 | 248 |
| Number of mines | 49 | 252 |
| Number of preparation plants | 5 | 61 |
| Net shipments of primary products[3/]....thousand short tons | 705 | 4,405 |
| Value of shipments, total.....thousand dollars | 3,021 | 22,206 |
| Net primary products[3/].....do. | 2,815 | 20,808 |
| Other products and services.....do. | 206 | 1,398 |
| Value added in mining.....do. | 1,893 | 17,468 |
| Number of persons engaged, total | 299 | 2,154 |
| Production and development workers | 219 | 1,802 |
| All other employees | 22 | 185 |
| Proprietors and firm members | 58 | 167 |
| Performing manual labor | 31 | 74 |
| Man-hours worked by production and development workers, total.....thousand | 399 | 3,123 |
| At mines, total.....do. | 317 | 2,408 |
| Underground.....do. | - | 958 |
| Open-pit.....do. | 310 | 1,137 |
| Surface (including mine shops and yards).....do. | 7 | 313 |
| At preparation plants.....do. | 82 | 715 |
| Man-hours spent on development and exploration work (included above).....do. | [4/]50 | [4/]114 |
| Tons of primary products per man-hours | 1.77 | 1.41 |
| Principal expenses designated below, total.....thousand dollars | 1,788 | 11,371 |
| Wages of production and development workers....do. | 603 | 5,670 |
| Salaries of all other employees.....do. | 101 | 928 |
| Minerals received for preparation.....do. | ) | ) 160 |
| Supplies[5/].....do. | 354 | ) 1,983 |
| Fuel.....do. | 277 | 639 |
| Purchased electric energy.....do. | 40 | 305 |
| Contract work.....do. | 413 | 1,686 |
| Purchased machinery installed.....do. | 219 | 1,292 |
| Capital expenditures, total.....do. | 175 | 1,327 |
| Development and exploration of mineral property.....do. | 32 | 79 |
| Preparation plant construction.....do. | - | 116 |
| Other construction.....do. | - | 68 |
| New machinery and equipment.....do. | 125 | 925 |
| Used plant and equipment.....do. | 18 | 139 |
| Horsepower rating of power equipment (prime movers and electric motors driven by purchased energy), total..... | 21,163 | 100,500 |
| Per production worker..... | 97 | 56 |

See footnotes at end of table.

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TABLE 2. - Comparative detailed statistics for the fire-clay industry in Missouri and the United States, 1954[1/ 2/] (Con.)

| Item | Missouri | United States |
|---|---|---|
| Prime movers | 20,336 | 82,097 |
| Electric motors driven by purchased energy | 827 | 18,403 |
| Horsepower rating of electric motors driven by energy generated at the establishment | - | - |
| Energy used.....million kw.-hr. equivalent | 146 | 300 |
| Coal.....thousand short tons | - | 3 |
| Fuel oils.....thousand barrels | 71 | 108 |
| Gas (natural and manufactured).....million cu.ft. | 1 | 31 |
| Electric energy purchased.....million kw.-hr. | 3 | 17 |
| Electric energy generated and used.....do. | - | - |
| Water intake, including mine water used....million gallons | 16 | 157 |
| Per production worker.....do. | 0.07 | 0.09 |

1/ 1954 Census of Mineral Industries; Clay, Ceramic, and Refractory Minerals; U.S. Dept. of Commerce, Bureau of the Census, Washington, D.C., pp. 14F-19.

2/ Statistics on mining operations carried on as secondary activities at manufacturing or other nonmining establishments (such as clay pits at clay products plants) are not included in this table. According to Bureau of Mines data for 1954, Missouri fire-clay production was 1,183,000 tons from 71 pits. Bureau of Mines data included clay sold or used at refractory or other clay-products plants.

3/ Represents net shipments (gross shipments, less minerals received for preparation) of the product indicated by the name of the industry. The quantity figure for mines included in manufacturing establishments includes clay produced and used in the same establishment.

4/ Revised.

5/ Includes products purchased for resale without further processing.

TABLE 3. - Fire-clay mine productivity of production workers in open pits in Missouri, 1941-45 and 1951-55

| County | Number of pits | | Tonnage, thousand short tons | | Productivity, tons per man-hour | |
|---|---|---|---|---|---|---|
| | 1941-45 | 1951-55 | 1941-45 | 1951-55 | 1941-45 | 1951-55 |
| Audrain | 5 | 10 | 1,260 | 462 | 1.72 | 3.57 |
| Callaway | 18 | 13 | 853 | 289 | 1.02 | 4.09 |
| Crawford | - | 4 | - | 13 | - | 1.34 |
| Franklin | 13 | 5 | 92 | 52 | 1.09 | 2.36 |
| Gasconade | 49 | 67 | 974 | 641 | .85 | 2.67 |
| Lincoln | 1 | 2 | 9 | 41 | 1.52 | 3.27 |
| Maries | 8 | 8 | 284 | 34 | .52 | 1.85 |
| Monroe | 2 | 4 | 22 | 52 | 1.20 | 3.46 |
| Montgomery | 19 | 13 | 1,242 | 330 | 1.41 | 2.99 |
| Osage | 10 | 15 | 489 | 139 | .72 | 1.79 |
| Phelps | 4 | 10 | 45 | 102 | 1.01 | 1.39 |
| St. Louis | 7 | 3 | 422 | 35 | 1.50 | 2.14 |
| Vernon | 1 | - | 5 | - | 1.25 | - |
| Warren | 5 | 10 | 213 | 78 | 1.30 | 3.46 |
| Total | 142 | 164 | 5,910 | 2,268 | 1.09 | 2.77 |

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## Transportation

The movement of clays in Missouri for the production of refractories in 1957 was estimated at 66 million ton-miles. The average distance from the pit to the plant ranged from 35 to 40 miles. At most plants materials were received by both truck and rail; at some plants all materials were received by rail. Clays received at Mexico, Vandalia, and Fulton from the Southern Fire-Clay District were received directly by truck or by truck to the nearest rail center for reshipment to the plant. Plants in the vicinity of Mexico received products from the Southern Fire-Clay District mostly by rail after a short shipment by truck to the nearest railhead. Many shipments were trucked from the mines to the nearest railhead on a line moving directly into Mexico, Farber, or the Vandalia area. An estimated 5 to 10 percent of Missouri clays was shipped to other producing areas as a blending material.

Table 4, a résumé of the tariffs filed by several contract miners and haulers with the Public Service Commission of Missouri, illustrates the high cost of truck transport. The rates shown in the table may not reflect accurately the actual costs of transporting clays from clay mines to refractories plants. The filing of these rates was in conformity with State regulations. The fees paid to contractors, based on a variety of operating conditions, include both mining and transportation costs. Common-carrier rates for transporting clays generally are not established.

The freight rate on calcined bauxite shipped from the east coast point of arrival to Missouri is $6 of a total price of $38 a ton at the plant.

TABLE 4. - Rate schedule for hauling clay by truck in Missouri, 1956 1/ 2/

| Distance of haul (miles) | Rate per ton (2,000 lb.) | Distance of haul (miles) | Rate per ton (2,000 lb.) |
|---|---|---|---|
| 1 and under..... | $0.15 | 35..... | $1.60 |
| 2..... | .22 | 40..... | 1.72 |
| 3..... | .30 | 45..... | 1.84 |
| 4..... | .38 | 50..... | 1.96 |
| 5..... | .45 | 55..... | 2.08 |
| 10..... | .70 | 60..... | 2.20 |
| 15..... | .95 | 65..... | 2.32 |
| 20..... | 1.20 | 70..... | 2.44 |
| 25..... | 1.34 | 75..... | 2.56 |
| 30..... | 1.48 | 100..... | 3.16 |

1/ Tariff No. 700, published May 31, 1956, by Motor Carriers Service, Tariff Bureau, Jefferson City, Mo.
2/ Includes 3 percent transportation tax.

To reduce hauling costs of clays, some carriers are changing from small dump trucks carrying 6 to 7 tons to tandem trucks carrying as much as 13 tons per load.

The economic significance of freight rates on moving raw materials relates to both the cost of manufacture and the long-term resource outlook.

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Plastic clays in the Southern Fire-Clay District usually are not exploited because freight rates make their use uneconomic.

## Production

In 1957, 1.7 million tons of fire clays was produced from 148 mines in Missouri. Over nine-tenths of this clay was used for the production of refractories. Seven of the eight refractories companies producing clays in Missouri used these clays for manufacturing refractories in the State. Twenty-nine contractors operated mines for these seven local companies. Eleven independent operators produced clays for sale to refractories companies; two refractories companies operated their mines with company personnel. During 1945-57, production of fire clays increased 59 percent. In terms of constant dollars, Gross National Product increased 45 percent during the same period.

TABLE 5. - Fire clay sold or used in Missouri, 1945-57

| Year | Tonnage | Year | Tonnage |
|---|---|---|---|
| 1945..... | 1,090,000 | 1951..... | 1,573,000 |
| 1946..... | 1,173,000 | 1952..... | 1,851,000 |
| 1947..... | 1,206,000 | 1953..... | 1,496,000 |
| 1948..... | 1,497,000 | 1954..... | 1,184,000 |
| 1949..... | 1,201,000 | 1955..... | 1,529,000 |
| 1950..... | 1,221,000 | 1956..... | 1,766,000 |
| | | 1957..... | 1,732,000 |

TABLE 6. - Fire clay mined in Missouri in 1957, by county

| County | Number of pits | Thousand short tons |
|---|---|---|
| Audrain..... | 18 | 464 |
| Callaway..... | 12 | 318 |
| Crawford..... | 2 | 5 |
| Franklin..... | 3 | 9 |
| Gasconade..... | 58 | 460 |
| Maries..... | 14 | 69 |
| Monroe..... | 4 | 79 |
| Montgomery..... | 13 | 108 |
| Osage..... | 14 | 66 |
| Phelps..... | 3 | 26 |
| Warren..... | 4 | 71 |
| Others1/..... | 3 | 57 |
| Total..... | 148 | 1,732 |

1/ Production was reported from one pit in each of Boone, Lincoln, and St. Louis Counties.

Missouri is the third ranking fire-clay-producing State, following Ohio and Pennsylvania. Because most of the fire clays produced in Missouri are used for refractories, the State in 1956 was the leading producer of fire clays for this purpose.

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TABLE 7. - Fire-clay production used for refractories in leading States, 1956

| State | Total fire-clay production | Percent of total fire-clay production used for refractories | Total tonnage of fire clay used for refractories |
|---|---|---|---|
| Missouri..... | 1,766,000 | 94 | 1,663,000 |
| Ohio..... | 3,165,000 | 35 | 1,119,000 |
| Pennsylvania..... | 2,443,000 | 59 | 1,447,000 |

## Other States

Fire clays for pottery, heavy clay products, and refractories are produced in Arkansas, Kansas, Mississippi, Oklahoma, and Texas. In 1957 over a million tons of fire clays was produced from the 33 open pits in this group of States. About 20 percent of this clay is used in the production of refractories. The major part of refractory clay is mined in Arkansas, but the quantity of fire clay produced in Texas and Mississippi for manufacturing refractories nearly equals Arkansas production.

There are 18 pits in Texas, 8 in Arkansas, 5 in Kansas, and 1 in Mississippi. Production of fire clay from one very small pit in Oklahoma is negligible.

TABLE 8. - Fire-clay production in other States in South Central United States, 1945-57

| Year | Arkansas, short tons | Texas, short tons | Kansas, short tons |
|---|---|---|---|
| 1945..... | 87,570 | 107,166 | (1/) |
| 1946..... | 178,246 | 200,050 | (1/) |
| 1947..... | 230,241 | 221,925 | (1/) |
| 1948..... | 273,540 | 259,128 | (1/) |
| 1949..... | 276,245 | 243,373 | (1/) |
| 1950..... | 256,042 | 307,026 | (1/) |
| 1951..... | 319,941 | 320,238 | (1/) |
| 1952..... | 386,111 | 358,466 | (1/) |
| 1953..... | 331,252 | 356,211 | (1/) |
| 1954..... | 325,294 | 347,247 | (1/) |
| 1955..... | (1/) | 437,595 | (1/) |
| 1956..... | 274,698 | 483,417 | 139,130 |
| 1957..... | 390,451 | 453,974 | 231,218 |

1/ Concealed.

## REFRACTORIES INDUSTRY

The seven-state area covered in this report includes 22 refractories plants. Nineteen of these plants produce fire-clay or high-alumina refractories, 2 produce high-quality silica refractories, and 1 produces dead-burned dolomite. Two plants are in Arkansas, 6 in Texas, and 13 in Missouri. Table 9 lists the manufacturers of refractories in the South Central United States, their location, and the types of refractories produced.

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TABLE 9. - Refractories plants in South Central United States, 1958

| State and manufacturer | Location of plant | Type of refractory |
|---|---|---|
| Arkansas: | | |
| Acme Brick Co..... | Perla | Fire clay. |
| Malvern Brick & Tile Co..... | Malvern | Do. |
| Mississippi: | | |
| H. K. Porter Co., Inc..... | Pascagoula | Basic. |
| Missouri: | | |
| General Refractories Co..... | Brentwood | Fire clay. |
| A. P. Green Fire Brick Co..... | Mexico | Fire clay and high alumina. |
| Harbison-Walker Refractories Co.. | Fulton | Fire clay. |
| Harbison-Walker Refractories Co.. | Vandalia | Fire clay and high alumina. |
| Laclede Christy Division, H. K. Porter Co., Inc..... | St. Louis (2 plants). | Fire clay, silica, and high alumina. |
| Mexico Refractories Co..... | Mexico | Fire clay and high alumina. |
| North America Refractories Co.... | Farber | Do. |
| Valley Dolomite Corp..... | Bonne Terre | Dead-burned dolomite. |
| Walsh Refractories Corp..... | St. Louis | Fire clay. |
| Walsh Refractories Corp..... | Vandalia | Fire clay and high alumina. |
| Wellsville Fire Brick Co..... | Wellsville | Do. |
| Western Stove Lining Works..... | Mexico | Fire clay, special shapes, and combustion-chamber linings. |
| Texas: | | |
| American Clay Forming Co..... | Tyler | Fire clay and insulating brick. |
| Elgin-Butler Brick Co..... | Elgin | Fire clay. |
| Elgin-Standard Brick Co..... | do. | Do. |
| General Refractories Co..... | Troup | Do. |
| A. P. Green Fire Brick Co..... | Sulphur Springs | Do. |
| Harbison-Walker Refractories Co.. | Athens | Fire clay and silica. |

In November 1958 H. K. Porter Co., Inc., completed a sea-water magnesia plant at Pascagoula, Miss., to produce periclase. A plant to produce basic refractory brick and shapes from this material was scheduled for production in February 1959. The refractories plant will produce basic brick with a range from 100 percent periclase to 100 percent chrome, specialties, cement, castables, ramming mixes, burned and chemically bonded materials, and metal-clad and un-clad brick. The basic refractories produced at this plant will have a strong competitive advantage in the Birmingham steel market and other markets in the Southwest.

Silica refractories are produced at Athens, Tex., and St. Louis, Mo. Both plants use novaculite from Arkansas as the principal raw material. The exceptional purity of this novaculite enables the manufacturers to produce a superduty silica brick. Superduty silica refractories must have less than 0.3 percent alumina.

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The silica products from these plants go primarily to the steel and glass industries of the area and contiguous areas. Development of silica refractories plants in the West and in the Birmingham, Ala., area has restricted the market for Missouri and Texas silica refractories in the past few years. Thus, additional growth of the industry will depend largely on an expansion of the market for silica brick in the area.

All fire-clay brick produced in Texas and Arkansas are made from Wilcox clays. Compared with plants in Missouri and other major producing areas, plants in Texas and Arkansas are small. Because Missouri is the major refractories-supplying area in the South Central United States, the following discussion is confined to refractories production in that State.

## Manufacturing Methods

Consumers continually are demanding refractories for higher temperatures and longer service life. The high cost of installation and the lost production during periods of repair are among the important motivating forces for this demand. The refractories industry is responding to these needs with improvements in quality control of raw materials and finished refractories.

Rising quality requirements have resulted in increased costs of raw materials and in shortages of some of the higher quality clays, notably flint fire clays.

Firebrick seldom is made of a single clay. Flint fire clays are used to impart high refractoriness; plastic clays for forming and bonding strength. Diaspore clays, because of their high alumina content, are used to give a higher degree of refractoriness than can be obtained with plastic and flint fire clays.

Grades of firebrick, according to ASTM Designation C27-41, must have the following minimum pyrometric cone equivalents: Low duty, 19; intermediate duty, 29; high duty, 31; and superduty, 33. In addition, high-temperature load tests and spalling tests are specified for all but low-duty firebrick.

Plastic materials are made into several grades similar to the different grades of firebrick. Plastic firebrick are made of a mixture of fire clay, brick grog, and plastic bonding clay. Plastics are installed by ramming chunks of the material into place to form a monolithic structure.

Castables are a blend of grog, calcined clay, cement, and clays. The choice of materials depends on service conditions.

Firebrick and shapes are made by the handmolding, stiff-mud, or dry-press methods. Since the development of the dry-press method, very little handmolding has been done in the refractories industry of Missouri; however, for special orders, the companies still maintain facilities for handmolding. In the stiff-mud process the clay is pugged, tempered, deaired, forced through a die in the shape desired, and cut by a mechanical wire cutter. Stiff-mud brick are dense and compact. In the dry-press method clay with low moisture content

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is fed into hydraulic presses and pressed into brick under high pressure. The dry-press method gives a suitable uniformity of size and also control over the strength and density of the brick. The brick has low spalling characteristics.

Brick are fired either in periodic kilns or tunnel kilns. In tunnel kilns the brick are moved through the firing zone on rail cars. The tunnel kiln, used for the production of most standard shapes, lends itself to high levels of production. Special shapes and very large shapes usually are fired in periodic kilns. In Missouri, natural gas usually is used for firing the kilns.

## Raw-Material Requirements by Type of Product

Intermediate-duty brick is made from plastic, semiplastic, and semiflint clays with some flint clay. Ladle brick also does not have much flint clay, but is composed largely of semiflint and plastic clays. High-heat-duty brick is 25 to 30 percent flint clay and the rest is plastic clays. Superduty brick ranges from 20 to 40 percent high-grade plastic clay and 60 to 80 percent flint clay. Some flint clays can be blended with larger quantities of plastic clays than others. High-alumina brick is a mixture of diaspore, burley, flint, and some bonding clays. Ninety-percent high-alumina brick has a little bonding clay and a fused alumina grain.

High-heat duty and intermediate-duty brick are a mixture of approximately four parts raw clay and one part grog. Superduty brick is all raw clay. High-alumina (50-percent) brick is six to seven parts raw clay and three to four parts grog. High-alumina (60-percent) brick is comprised of about equal parts of raw clay and grog. High-alumina (70-percent) brick is about one-third raw clay and two-thirds grog. Stiff-mud brick is made mainly from raw clay.

Plastic materials are 30 to 40 percent plastic clays and the rest grog, superduty, or special materials.

Castables are a blend of grog, calcined clay, cement, and clays.

Using another system of classification of raw materials, superduty brick is composed of two-thirds superduty clay (P.C.E. 33 or more) and one-third bond (plastic) clay (P.C.E. 32-1/2 to 33). About 4.5 tons of clay is used to manufacture 1,000 brick.

High-alumina brick is 10 to 20 percent plastic bond clay (P.C.E. 32-1/2 to 33) and 80 to 90 percent high-alumina clay of some type--burley, diaspore, or bauxite. Five tons of raw material is used per 1,000 brick.

## Substitution of Raw Material

To a large extent, Missouri diaspore clays have been replaced by calcined bauxite imported from British Guiana. British Guiana calcined bauxite contains 88 to 90 percent alumina, compared with Arkansas bauxite, which is 73 to 74 percent alumina. The Arkansas bauxite also has a higher percentage of

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impurities. Bauxite is calcined before export to the United States, because 30 percent of the total weight is lost in the kiln.

In 1954, 14,840 long tons of calcined bauxite, equivalent to 23,000 long tons of dried bauxite, was consumed by the refractories plants of Missouri. A small quantity of domestic bauxite is included in this figure.

Arkansas kaolinitic clays have replaced, to a certain extent, Missouri flint clays in superduty brick. One of the disadvantages of kaolinitic clays is that they must be calcined. Flint and kaolinitic clays have about the same P.C.E.

## Labor

Although the wage per man-hour in the refractories industry of Missouri in 1954 was lower than in other major clay-refractories-producing States, the average annual wage of refractories production workers in Missouri was the highest of the States producing clay refractories (6 percent higher than the national average). The average annual wage for the refractories industry in Missouri increased from $1,141 in 1940 to $4,664 in 1956, a more than fourfold increase.

TABLE 10. - Average annual and man-hour wages in Missouri and other major clay-refractory-producing States, 1954 1/ 2/

| Region | Average annual wage, all employees | Average annual wage per production worker | Average wage per man-hour for production worker |
|---|---|---|---|
| Missouri | $4,145 | $3,749 | $1.81 |
| Pennsylvania | 3,788 | 3,571 | 1.99 |
| Ohio | 3,630 | 3,359 | 1.90 |
| Kentucky | 3,275 | 3,052 | 2.08 |
| Illinois | 4,536 | 3,748 | 2.07 |
| Maryland | 3,333 | 3,192 | 1.95 |
| United States | 3,844 | 3,523 | 1.89 |

1/ U.S. Dept. of Commerce, Bureau of the Census, 1954 Census of Manufacturers, Advance Report, Cement and Structural Clay Products, October 1956, p. 4.
2/ States ranked by order of magnitude of value added by manufacture of clay refractories.

Refractories workers in Missouri are represented by the United Brick and Clay Workers of America, which is affiliated with the American Federation of Labor. The refractories industry, as a whole, usually follows steel in its wage contracts. Agreements between union and company provide for uniform schedules of pay, seniority provisions, vacations with pay, insurance, death benefits, hospitalization, accident, and sickness benefits (51, pp. 72-74). Not all plants in Missouri are unionized.

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TABLE 11. - Employment in the refractories industry in Missouri[1/]

| Year | Total employment | Total annual wage | Average annual wage |
|---|---|---|---|
| 1940..... | 3,494 | $3,986,524 | $1,141 |
| 1945..... | 3,781 | 7,805,500 | 2,064 |
| 1950..... | 4,040 | 12,934,172 | 3,202 |
| 1951..... | 4,857 | 16,428,976 | 3,383 |
| 1952..... | 5,195 | 18,360,168 | 3,534 |
| 1953..... | 4,842 | 18,230,584 | 3,765 |
| 1954..... | 4,362 | 17,316,340 | 3,970 |
| 1955..... | 3,985 | 16,752,628 | 4,204 |
| 1956..... | 4,735 | 22,084,220 | 4,664 |

1/ Division of Employment Security, Dept. of Labor and Industrial Relations. Wages and number of employees are based on first quarter average for each year. Compiled from microfilm records of reports by all refractories producers in the State.

## Production

The proportional value of refractories produced in Missouri to value of refractories produced in the United States has increased steadily. The value of shipments of refractories increased from 10 percent of the national total in 1909 to 17 percent in 1929 (51, p. 24) and to 29 percent in 1954 (59, p. 32B-7) because of the production of high-alumina and superduty refractories (high-quality and high-value products) as well as to larger tonnages of other refractories.

The total value of clay refractories shipped from plants in the South Central United States in 1954 was $44.8 million. Eighty-eight percent of these refractories was produced in Missouri. The South Central United States produced the following portions of total National production in 1954:

| | Percent |
|---|---|
| Standard fire-clay brick..... | 22 |
| Superduty brick..... | 85 |
| High-alumina brick..... | 62 |
| Plastic, castable, and ramming mixes..... | 37 |

The estimated net income resulting from production and shipment of refractories (table 12) in the South Central United States compares favorably with returns to refractories plants in other areas. The general economic health of Missouri refractories plants and a probable growth in the Missouri natural-market area would seem to establish a strong competitive position for the State refractories industry.

Fuels represent approximately 10 percent of the variable costs of manufacture. The savings in fuel due to nearness to the gasfields of the Southwest can be a contributing factor to maintaining the competitive position of the industry.

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Refractories companies spent $1,121,000 on capital expenditures in Missouri in 1954, according to the 1954 Census of Manufactures. The value added by manufacturers in producing refractories was $25,765,000. This represents 29 percent of the value added by manufacturers in the Nation for production of clay refractories.

TABLE 12. - Value of shipments, production costs, and net income of refractories plants in South Central United States and all other States, 1954

| | South Central United States | Other States |
|---|---|---|
| Value of shipments f.o.b.1/ | $44,751,000 | $91,618,000 |
| Total 1954 payrolls1/ | 18,515,000 | 37,089,000 |
| Total materials, fuels, and services1/ | 15,161,000 | 32,455,000 |
| Depreciation, depletion, and amortization2/ | 3,625,000 | 7,421,000 |
| State, local, and Federal taxes2/ | 3,850,000 | 7,879,000 |
| Net income | 3,600,000 | 6,774,000 |
| Percent return on value of shipments | 8.0 | 7.3 |

1/ 1954 Census of Manufacturers.

2/ Estimated by senior author, based on percentage of gross sales from average of major refractories companies. Financial data taken from group of companies with plants in various parts of the United States. Proportion of gross sales denoted by State, local, and Federal taxes considered representative. Share of depreciation, depletion, and amortization consistent in sample. Because of relatively standard productive equipment and procedures, these figures considered reliable for companies operating in Missouri.

## Consumption

The South Central United States is a net exporter of refractories. Missouri refractories plants ship about 95 percent of their production out of the State. Because of a relatively small consumption of refractories in Arkansas, this State also is an exporter. Other States in the area are dependent essentially on imports of refractories from producing centers. Texas, for example, produces only a small part of its total refractories demand.

Most high-alumina, superduty, and silica refractories consumed in the area are produced by refractories manufacturers in the South Central United States. A large part of the fire-clay refractories of high-heat duty and lower consumed in the area is produced in Missouri, Arkansas, and Texas. Those refractories of high-heat duty or lower entering the area do so largely because of proximity to other refractories-producing centers or because of favorable freight rates.

Based on data compiled by the ICC, an estimated 23 percent of the refractories tonnage consumed in the area was shipped in from Pennsylvania, Maryland, Illinois, Kentucky, and Alabama (table 13). All other States supplied less than 7 percent of the total tonnage. Although only 30 percent of the total tonnage consumed in the area is imported from outside the area, the value of area imports is 40 to 45 percent of total consumption, because most of these shipments were higher priced basic, silica, and specialty products.

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TABLE 13. - Sources of supply of refractories consumed in South Central United States[1/]

| Source | Percent of total tonnage shipped to South Central United States[2/] |
|---|---|
| Missouri | 51.8 |
| Texas | 14.5 |
| Pennsylvania | 6.7 |
| Maryland | 5.3 |
| Illinois | 4.8 |
| Arkansas | 4.3 |
| Kentucky | 3.2 |
| Alabama | 2.5 |
| All others | 6.9 |

1/ ICC, Bureau of Transport Economics and Statistics, carload waybill statistics, 1948-55, State-to-State distribution of manufacturers and miscellaneous and forwarder traffic (C.L.), traffic and revenue.

2/ The table does not represent percent of value of shipments. Basic, specialty refractories, and some silica are imported from outside the region. The value of these items is generally much higher per ton than fire-clay refractories--for example, Maryland and Pennsylvania basic refractory shipments.

TABLE 14. - Estimated consumption of refractories in South Central United States in 1954, by type of product

| Products | Value |
|---|---|
| Clay refractories: | |
| Fire-clay brick and shapes | $4,500,000 |
| Superduty brick and shapes | 1,250,000 |
| High-alumina brick and shapes | 750,000 |
| Other | 3,250,000 |
| Mortar | 750,000 |
| Plastics and castables | 1,575,000 |
| Nonclay refractories: | |
| Basic | 3,000,000 |
| Silica | 1,350,000 |
| Other | 1,250,000 |
| Mortar | 375,000 |
| Plastics and castables | 450,000 |
| Total | 1/18,500,000 |

1/ An estimated additional $2 million was produced by the horizontal-retort zinc industry at its plants for self use.

It is estimated that Texas consumes slightly more than half the total quantity of refractories consumed in the area, followed by Missouri, Louisiana, Oklahoma, and Kansas. In 1954 (year of the sample survey) Arkansas

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and Mississippi together consumed only slightly more than $1 million worth of refractories of all types.

TABLE 15. - Estimated consumption of refractories in South Central United States in 1954, by States

| State | Value |
|---|---|
| Arkansas | $570,000 |
| Kansas | 1,000,000 |
| Louisiana | 1,700,000 |
| Mississippi | 580,000 |
| Missouri | 3,300,000 |
| Oklahoma | 1,100,000 |
| Texas | 10,250,000 |
| Total | 18,500,000 |

About two-thirds of the total value of refractories consumed in the area is fire-clay, superduty, or high-alumina refractories. The remainder is essentially basic and silica refractories and miscellaneous specialty products mostly imported from other areas.

Of the silica refractories consumed in the area, part is produced in St. Louis, Mo., and Athens, Tex., and part imported from other producing areas. The indicated market demand for silica refractories of $1,350,000 is comparatively small. Shipments to the area are about 3.5 percent of total national shipments of silica brick and shapes for 1954. In the light of existing capacity in the area and presently low rates of consumption, expansion of silica refractories facilities in the South Central United States does not appear likely.

The estimated market demand of $3 million for basic refractories in the South Central United States during 1954 would not encourage the construction of basic refractories plants for this market alone. The potential expansion of steel capacity and other industrial segments in the area will improve this situation considerably. Basic refractories development will be based partly on potential market expansions and sea-water magnesia. The plant at Pascagoula, Miss., will use magnesia from sea water to produce basic refractories. Proximity to the Alabama steel area will strengthn the market position of the plant.

Although the demand for refractories in the area is predominantly from from the iron and steel industry, that industry group in this area uses considerably less of total consumption than the national average for iron and steel. Approximately equal quantities of refractories are consumed by the chemical and petroleum refining, cement and lime, and glass industries (table 16). The distinguishing feature in the consumption pattern of the South Central United States is the relatively large share of refractories consumed under the category of Others. Included in this category are numerous small consumers such as lumber mills, paper mills, sugar refineries, cotton gins, sulfur-recovery plants, carbon-black plants, natural gasoline plants, and miscellaneous industries using small-scale stills and heaters.

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TABLE 16. - Estimated consumption of refractories in South Central United States in 1954, by industry group

| Industry group | Percent of total value |
|---|---|
| Iron and steel | 32 |
| Other metallurgical | 5 |
| Chemical and petroleum refining | 12 |
| Cement and lime | 10 |
| Glass | 10 |
| Structural clay products | 7 |
| Others | 24 |

According to the Business and Defense Services Administration, U.S. Department of Commerce, national consumption of all refractories was as follows:5/

| | Percent |
|---|---|
| Iron and steel | 65 |
| Other metallurgical industries | 10 |
| Chemical and refining, including oil refineries, carbon-black plants, and chemical industries | 15 |
| Remaining industries, including cement, glass, structural clay products, etc | 10 |

The pattern in the area is one without the overwhelmingly important refractories-consumer classes that exist in the heavily industrialized East.

## Trends

The use of refractories in large boilers in the electric-utility industry has not been appreciable for the past 15 years. Although electric-power consumption in the area has expanded greatly, development of the tangent-tube boiler has shielded refractories to the extent that replacement is infrequent. The utility industry, formerly a relatively large consumer of refractories, now uses only an estimated 2 percent of the total consumption of refractories in the area.

The chemical industry still uses a considerable quantity of various types of refractories in its boilers because the size of the operation does not justify the installation of more expensive tangent-tube units. Because of the expansion of petrochemical and other chemical industries in the area, particularly in the gulf coast area of Texas and Louisiana, consumption of refractories by the chemical industry will continue to grow.

5/ Neblett, H. W. (Chief, Facilities, Raw Materials and Refractories Branch), Estimate in a letter dated February 23, 1956: Iron and Steel Division, Business and Defense Services Administration, U.S. Department of Commerce.

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About 60 percent of the total consumption by the petroleum-refining industry is plastic and castables; the remainder is largely firebrick, mortar, and cement. With the large expansion of the catalytic-cracking process, temperature requirements have been lowered considerably; consequently, refractories requirement have lessened to some extent. In straight-run distilling units, the industry uses high-heat-duty and superduty brick.

Foundries are shifting from the use of refractory shapes to monolithic linings.

The rise in production and consumption of specialty products--plastics, castables, and ramming mixes--has been notable. There has been a continuous growth in demand for these products, and it is anticipated that this growth will continue. The largest users of castables are the steel, petroleum, and nonferrous industries.

Railroad conversion from steam to diesel engines has curtailed the consumption of refractories by this industry. The steam boilers used considerable quantities of standard fire-clay refractories. The loss of this market is felt particularly by the smaller refractories plants servicing the needs at local rail-repair terminals.

Some cement plants, particularly in the gulf coast area, have shifted to the use of basic refractories in their rotary kilns. Current users of this type of refractory have expressed satisfaction despite the much higher initial cost.

Requirements for high-quality fire-clay refractories have become greater in spite of their higher price, and consumers predict that the trend toward replacing lower quality refractories with higher quality material will continue because extended service can be obtained. The rising cost of installing refractories is a large factor in this decision.

The large share of refractories going to miscellaneous small consumers is economically significant. It is not feasible to locate a refractories plant on the basis of so diversified and widespread a market. This factor may act to strengthen the long-term position of local plants supplying the area with fire-clay, superduty, and high-alumina refractories.

## Growth of Market

Between 1940 and 1954 the estimated rate of increase in consumption of refractories in the South Central United States was a little more than the national increase of 200 percent. The increased consumption was due to industrial expansion in many sections of the economy. During this period, cement production in the area increased 171 percent to a total of over 50 million barrels, while the national output increased only 111 percent. There are now 30 cement plants in the area. Lime production increased 175 percent to nearly 2 million tons, while national production was only 77 percent greater. There are now 20 lime plants in the area. Crude-oil refining capacity increased about 85 percent and cracked-gasoline capacity 124 percent, following the

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national pattern. Natural gasoline production capacity in the area grew 303 percent as compared with national growth of 244 percent. Carbon-black production in 1954 was more than twice that of 1940.

Comparable figures for the years 1940 through 1954 were not available for chemicals and structural clay products. Between 1947 and 1954, however, the production of building brick in the South Central United States increased from 648 to 980 million, an increase of 51 percent. This compares with a 23-percent increase for the United States. From 1947 to 1954, the value of chemicals and chemical-products output in the South Central United States increased 131 percent to nearly $1.5 billion as compared with a 71-percent increase for the United States. The chemical industry of the gulf coast of Louisiana and Texas is one of the most rapidly growing segments of the area's economy.

Although consumption of refractories in the area is approximately 8 percent of the national total, it is anticipated from the present rate of growth that consumption in the area will exceed 10 percent of the national total in a few years.

It is expected that steel-production capacity in the area will be increased to meet the growing regional-market demand for steel. The rate of the growth of steel consumption should exceed that of the Nation. In particular, steel requirements for oil-well drilling pipe, oil and gas pipelines, and a vastly expanded fabricating industry will continue to grow. Because steel is the major consumer of refractories, as new production facilities are built, refractories consumption will rise.

Whether steel required to meet this demand will be manufactured in the South Central United States is contingent on further development of the area's iron ore and coal resources or on evolution of an industry based on imported iron ores reduced with Oklahoma, Alabama, or imported coals. In the spring of 1954 the Armco Steel Co. announced a plan to build a million-ton yearly capacity steel plant and a seamless pipe mill in the Southwest, probably at Houston, Tex. Although the plant may not be constructed for several years, it is possible that this plant, or another, will be built in the Southwest within 5 to 10 years.

The steel-production capacity now is centered at Houston and Daingerfield, Tex., and at Kansas City, Mo. A small open-hearth plant is at Sand Springs, Okla. There are also some small to medium-size electric-furnace operations in the area.

The number of foundries in the area is small, compared with that of the United States. For instance, there are 231 gray-iron foundries and 268 nonferrous foundries, which represent 5 to 6 percent of the national total. However, this number is expected to increase abruptly within the next decade, as numerous small local industries evolve to meet consumer demands for local products.

Other sections of the metallurgical industry are expected to grow in importance to the economy.

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TABLE 17. - Indicators of economic growth in South Central United States, 1939-54[1/]

| State | Manufacturing employment | | | | Value added by manufacture (thousand dollars) | | | |
|---|---|---|---|---|---|---|---|---|
| | 1939 | 1947 | 1954 | Change 1939-54, percent | 1939 | 1947 | 1954 | Change 1939-54, percent |
| Arkansas..... | 41,183 | 65,321 | 78,391 | +91 | 66,444 | 265,144 | 457,047 | +588 |
| Kansas..... | 42,564 | 74,624 | 131,017 | +208 | 117,391 | 461,061 | 1,049,291 | +794 |
| Louisiana.... | 87,770 | 132,464 | 144,757 | +65 | 198,527 | 694,074 | 1,181,649 | +495 |
| Mississippi.. | 52,064 | 76,671 | 90,641 | +74 | 72,661 | 300,184 | 467,625 | +544 |
| Missouri..... | 220,269 | 327,515 | 368,479 | +67 | 581,804 | 1,623,145 | 2,727,266 | +369 |
| Oklahoma..... | 37,585 | 55,403 | 79,851 | +112 | 101,782 | 341,027 | 580,633 | +470 |
| Texas..... | 163,978 | 297,053 | 410,364 | +150 | 448,523 | 1,727,464 | 3,501,706 | +681 |
| Total..... | 645,413 | 1,029,051 | 1,303,500 | +102 | 1,587,132 | 5,412,099 | 9,965,217 | +528 |
| United States | 9,527,000 | 14,300,000 | 16,135,000 | +69 | 24,487,000 | 74,339,000 | 116,001,000 | +374 |

| | Population | | | Personal Income (million dollars) | | |
|---|---|---|---|---|---|---|
| | 1940 | 1950 | Change, percent | 1940 | 1950 | Change, percent |
| Arkansas..... | 1,949,387 | 1,905,705 | -2 | 501 | 1,532 | +206 |
| Kansas..... | 1,801,028 | 1,898,230 | +5 | 762 | 2,650 | +248 |
| Louisiana..... | 2,363,880 | 2,677,370 | +13 | 861 | 2,937 | +241 |
| Mississippi..... | 2,183,796 | 2,177,445 | - | 474 | 1,588 | +235 |
| Missouri..... | 3,784,664 | 3,943,310 | +4 | 1,982 | 5,713 | +188 |
| Oklahoma..... | 2,336,434 | 2,229,665 | -5 | 867 | 2,517 | +190 |
| Texas..... | 6,414,824 | 7,685,665 | +20 | 2,776 | 10,376 | +274 |
| Total..... | 20,834,013 | 22,517,390 | +8 | 8,220 | 27,313 | +232 |
| United States.... | 131,669,275 | 150,697,361 | +14 | 78,522 | 225,464 | +187 |

1/ U.S. Dept. of Commerce, Bureau of Census, Census of Manufactures, 1947; Census of Manufactures, 1954; Census of Population, 1950.

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During and since World War II, the aluminum industry of the South Central United States expanded rapidly. Alumina capacity built or under construction is 81 percent that of the Nation; 31 percent of the aluminum-metal production capacity is in the area. The industry uses mainly fire-clay refractories.

About 88 percent of the horizontal-retort zinc-smelting capacity of the Nation is at Fort Smith, Ark., Bartlesville, Blackwell, and Henryetta, Okla., and Amarillo and Dumas, Tex.

Other metal producers in Texas are the antimony smelter at Laredo, the tin-tungsten smelter at Texas City, the lead and copper smelters and electrolytic and fire refineries at El Paso, the magnesium plants at Freeport and Velasco, and a small manganese-ore reduction plant at Houston. A lead smelter and refinery is at Herculaneum, Mo. There also are several small secondary smelters in the area. These plants use a relatively small part of all refractories consumed in the area, but periodic major furnace overhauls require substantial quantities of refractories.

There were 5 centers of metal-working employment in the South Central United States that employed over 20,000 persons: (a) Vicinity of Wichita, Kans., in the aircraft and oilfield-equipment industries, and iron, steel, and nonferrous foundries; (b) the metropolitan Kansas City area, in a large steel mill, oilfield-equipment plants, secondary smelters, and foundries; (c) Houston, Tex., in aircraft, iron and steel, truck assembly, ship and boat building, secondary metal products, and oilfield-equipment industries, and iron and steel foundries; and (d) Dallas and (e) Fort Worth, Tex., in aircraft, automotive, oilfield-equipment industries, and iron and steel foundries. Between 5,000 and 20,000 people are employed in metal working in each of the following cities: New Orleans, La., St. Louis, Mo., Oklahoma City and Tulsa, Okla., and Port Arthur, Corpus Christi, and Beaumont, Tex. In addition, there are 33 other concentrations of metal-working plants employing between 1,000 and 5,000 employees (54).

There are 26 glass plants in the South Central United States. A window-glass plant and a pressed- and blown-glassware plant are in Fort Smith, Ark. Two fiberglass plants are at Kansas City, Kans. At Shreveport, La., there is a window-glass plant. Bottle- and hollow-glass-ware plants are at Gulfport and Jackson, Miss. In Missouri, there are a polished plate-glass plant at Crystal City, a foam-glass insulation plant at Sedalia, and a glass plant at St. Louis. There are 12 glass plants in Oklahoma--3 in Okmulgee, 2 in Muskogee, and 2 in Sapulpa; and 1 plant each in Ada, Cedars, Henryetta, Sand Springs, and Tulsa. In Texas, glass plants are at Brownwood, Grandview, Palestine, and Waco (33).

## Distribution of Refractories Produced

Refractories produced in Arkansas and Texas are consumed almost entirely in the South Central area. Missouri refractories, on the other hand, are consumed in almost every State in the Nation and in many foreign countries.

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Missouri refractories are firmly established in foreign markets, particularly in Latin America. Mexico at one time was a large consumer of refractories from plants in both Missouri and Texas. With the imposition of a Mexican tariff in the 1950's, domestic plants lost most of the market in Mexico. The loss was more serious to the Texas industry because of the large shipments it had been making. Several refractories companies have begun working with Mexican industrialists to establish additional manufacturing facilities in Mexico.

The shipment of Missouri refractories to Louisiana (fig. 7) exceeds consumption in Louisiana because exports are included. Much of the 4.5 percent total Missouri refractories (estimated value, $2 million) shown as shipped to Louisiana is for export from the Port of New Orleans. According to the records of the New Orleans Custom District, $1,207,220 worth of refractories was exported through that port in 1954.6/

Figure 7, showing distribution of Missouri refractories, is based on a sample of shipments compiled by ICC. Percentages were based on the pattern of shipments over the entire period 1948-55. Thus, the degree of reliability was increased in terms of destination of shipments and percentage terminating in each State. Percentages were determined by totaling tonnage of shipments to each State for the 8 years and then computing the percent of total tonnage shown in the sample. Because the ICC sample is small, the tabulation did not always show shipments to individual States for single years. Quantitative and geographical errors were compensated by using the entire series of years.

## Marketing Procedures

According to the Census of Business for 1939 (the latest available figures), the distribution of clay refractories was approximately 30 percent through manufacturer outlets, 64 percent directly to industrial users, and 6 percent through wholesale jobbers, retailers, and small direct exports. Statistics are not available on the distribution and marketing procedures employed by Missouri refractories producers, but it is estimated that local dealers are used to a far greater extent than most other refractories manufacturers. The wide diversity of the market area is responsible for this type of marketing operation. Some companies that attempted to develop their own outlets have returned to a dealer-sales-manager-type operation. Others still are trying to establish the company-outlet arrangement. Sales directly by the manufacturer permit handling of split stocks, but the expense of such an organization may be uneconomical. Some companies indicated a preference for letting dealers handle their products on commission and maintain the expense of an inventory. Certain products are handled entirely by the companies.

## Other Market Factors

### Location Analysis of Missouri Refractories Plants

Missouri refractories plants are oriented to raw materials rather than to markets. Since deposits of fire clays suitable for the production of

6/ Compiled from records in New Orleans Customs District Office, New Orleans, La.

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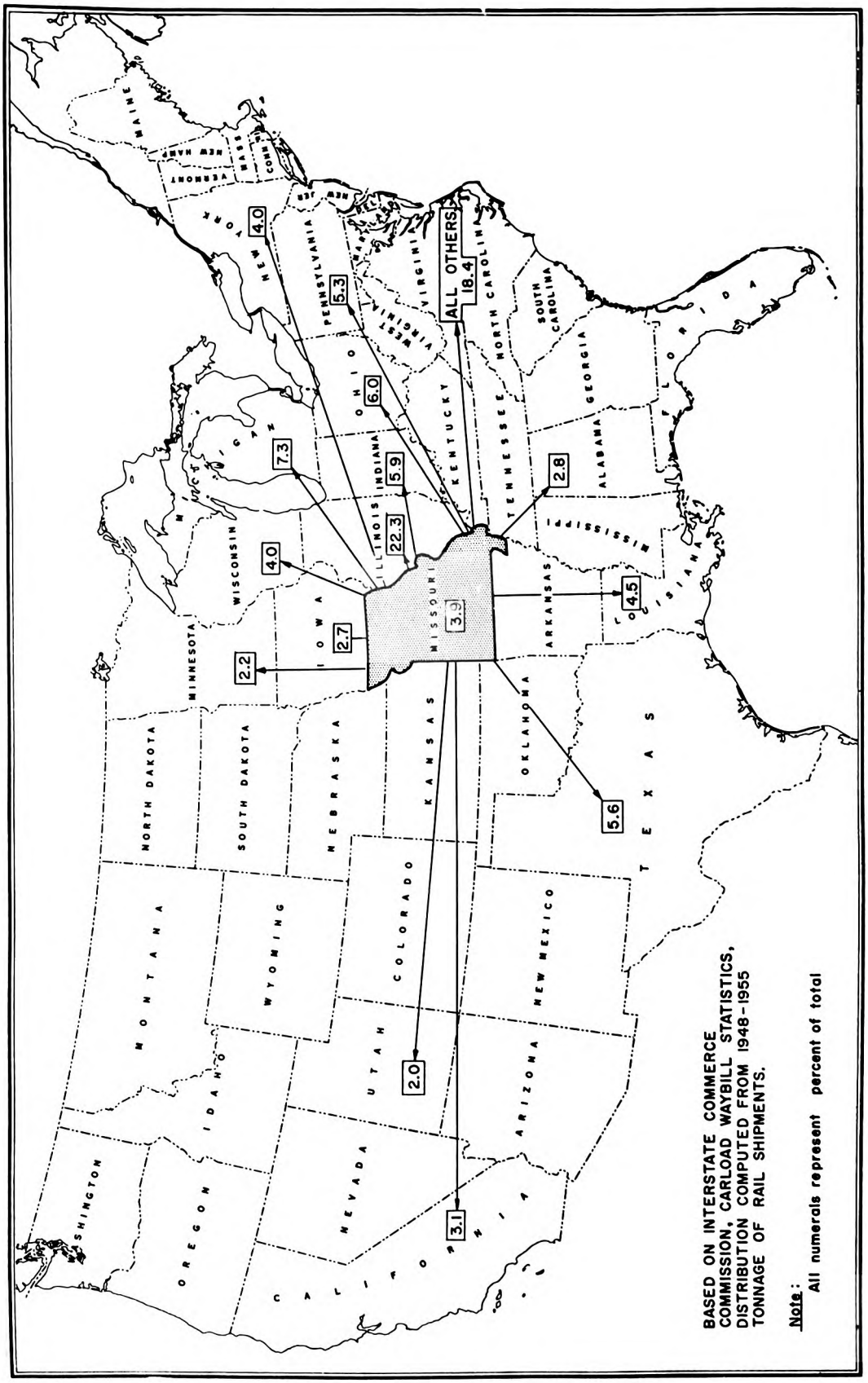


FIGURE 7. - Distribution of Missouri Refractories.

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refractories are more limited than deposits of common clays, all refractories plants are, to some extent, oriented to raw materials. In addition to Missouri, Ohio and Pennsylvania are leading refractories-producing areas. Other plants are in Kentucky, Illinois, New Jersey, Maryland, and California. Although Missouri refractories plants are a considerable distance from the heavy industry in the East, several compensating economic forces enable the area to maintain its important position in the industry.

The area has sizable supplies of high-quality refractory clays. These clays lie under relatively shallow overburden, permitting the more economical open-pit mining. In Ohio 31 percent of fire clays is mined underground; in Pennsylvania, 44 percent. Economic supplies of flint fire clay, burley clay, and diaspore in Missouri for the production of superduty and high-alumina refractories have enabled the industry in the State to produce a major part of these refractories. These higher quality and higher priced refractories can be shipped greater distances than less-expensive refractories because freight charges constitute a smaller proportion of the total cost.

Its central location gives Missouri a competitive advantage over eastern manufacturers to the market areas of the Midwest, Southwest, and West. With additional development of the midwestern and western industries and the rapid rate of industrialization in the Southwest, Missouri refractories will strengthen their market position relative to other refractories-producing areas.

Refractories plants are becoming increasingly complex, requiring specialized equipment and increased scientific knowledge and technology, best carried out by large-scale operations. Furthermore, the quality raw materials available in Missouri permit a diversity of products suitable for an extended market area. The predominance of Missouri in production of superduty and high-alumina refractories, and plastics, ramming mixes, castables, and other specialty products demonstrates the capacity of large-scale operations and diversity of products to extend the market area.

In many areas raw materials are available to produce refractories suitable for the needs of local industries, consequently many refractories plants are built near local markets. Most refractories companies operating in Missouri have either widespread operations throughout the Nation or are Missouri industries that have extended their market area by acquiring plants servicing local markets in other market areas. Thus, the Missouri refractories industry is a compromise of raw-materials location and economies of scale on one hand and of freight advantages for locating subsidiaries near the market on the other. Other locational advantages are the proximity of the area to the abundant supply of natural gas in the Southwest and the available supply of local labor. The man-hour wage of $1.81 in 1954 for labor in Missouri refractories plants was the lowest of the major producing areas in the Nation. The average annual wage per production worker, however, was the highest.

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## Freight Rates

Data in tables 18, 19, 20, and 21 were compiled by the railroad operating at the point of origin. As shown in table 18, the Missouri refractories industry enjoys a favorable freight-rate advantage throughout most of the South Central United States as compared with other refractories-producing areas. For shipments to Birmingham, Minneapolis, and Milwaukee, Missouri refractories producers have either a freight advantage over most areas or competitive rates. However, shipments to eastern points have a disadvantage in freight rates.

TABLE 18. - Comparison of freight rates for firebrick

(Rate per net ton)

| Destination | Origin | | | | |
|---|---|---|---|---|---|
| | Mexico, Mo. | Oak Hill, Ohio | Clearfield, Pa. | Joliet, Ill. | Olive Hill, Ky. |
| Birmingham, Ala..... | $9.60 | $9.60 | $12.37 | $10.42 | $8.80 |
| Little Rock, Ark..... | 7.00 | 11.40 | 13.20 | 9.80 | 11.40 |
| Chicago, Ill..... | 6.30 | 7.03 | 8.16 | 3.69 | 7.56 |
| Wichita, Kan..... | 7.40 | 12.20 | 14.20 | 9.80 | 14.84 |
| New Orleans, La..... | 10.20 | 10.80 | 14.23 | 12.21 | 10.60 |
| Detroit, Mich..... | 6.92 | 5.92 | 7.20 | 6.02 | 6.40 |
| Minneapolis, Minn..... | 7.26 | 9.50 | 15.72 | 6.11 | 11.91 |
| Jackson, Miss..... | 9.60 | 10.80 | 13.29 | 11.16 | 10.60 |
| Kansas City, Mo..... | 5.60 | 13.11 | 14.13 | 8.00 | 12.73 |
| St. Louis, Mo..... | 2.80 | 8.11 | 9.36 | 5.71 | 8.23 |
| Buffalo, N. Y..... | 8.56 | 6.92 | 6.02 | 7.37 | 7.44 |
| Cleveland, Ohio..... | 8.23 | 4.50 | - | 7.03 | 6.03 |
| Tulsa, Okla..... | 7.40 | 12.00 | 14.00 | 10.60 | 13.20 |
| Pittsburgh, Pa..... | 8.56 | 5.92 | 5.53 | 7.37 | 6.40 |
| Dallas, Tex..... | 11.40 | 13.40 | 15.00 | 12.40 | 13.20 |
| Houston, Tex..... | 11.40 | 14.20 | 15.40 | 13.20 | 13.60 |
| Milwaukee, Wis..... | 6.92 | 7.49 | 8.62 | 4.59 | 8.09 |

Table 19 indicates that shipments of basic brick from Baltimore, Md., to Houston, Tex., and Kansas City, Mo., have a competitive advantage over these from Plymouth Meeting, Pa., and Moss Landing, Calif.

TABLE 19. - Comparison of freight rates for basic brick

(Rate per net ton)

| Destination | Origin | | |
|---|---|---|---|
| | Plymouth Meeting, Pa. | Baltimore, Md. | Moss Landing, Calif. |
| Houston, Tex..... | $15.60 | $11.93 | $20.12 |
| Kansas City, Mo..... | 14.72 | 13.60 | 20.12 |

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Silica brick produced in Athens, Tex., has a competitive advantage in freight rates over other silica refractories-producing areas, except to St. Louis (table 20). For shipments to the Houston area, for example, the rates are about one-fourth the rates from Portsmouth, Ohio, and Mount Union, Pa.

TABLE 20. - Comparison of freight rates for silica brick

(Rate per net ton)

| Destination | Origin | | |
|---|---|---|---|
| | Portsmouth, Ohio | Mount Union, Pa. | Athens, Tex. |
| New Orleans, La..... | $10.80 | $14.23 | $8.00 |
| Jackson, Miss..... | 10.80 | 13.29 | 8.60 |
| Kansas City, Mo..... | 13.11 | 14.13 | 8.20 |
| St. Louis, Mo..... | 8.11 | 9.36 | 10.40 |
| Okmulgee, Okla..... | 16.11 | 14.20 | 6.80 |
| Houston, Tex..... | 14.20 | 15.40 | 3.60 |

TABLE 21. - Freight rates for firebrick shipments from Athens, Tex.

| Destination | Rate per ton |
|---|---|
| Birmingham, Ala..... | $10.60 |
| Little Rock, Ark..... | 6.80 |
| New Orleans, La..... | 8.00 |
| Jackson, Miss..... | 8.60 |
| Tulsa, Okla..... | 7.20 |
| Dallas, Tex..... | 2.20 |
| Houston, Tex..... | 3.60 |

Superduty and other grades of firebrick are shipped at the same rates; for superduty brick freight is therefore a smaller percentage of the total cost. For example, for a shipment of high-heat-duty refractories to Birmingham, the freight charge represents about 8 percent of the f.o.b. cost. The shipping charge on an equivalent weight of superduty brick, however, is only 4 percent of the total value. This accounts partly for a greater market range for higher quality refractories.

## Prices

The prices of Missouri first-quality refractories are essentially the same as prices in other producing areas. The multiple-basing-point price system existing in the midforties was removed in 1948 by order of the Federal Trade Commission. Currently, an f.o.b.-producing-point basis is employed by Missouri refractories companies.

As shown in figure 8, the price index of fire-clay brick has been rising continually. This is a reflection of the greater cost incurred with higher requirements as well as a general price increase. A comparison of changes in the price indexes of other similar construction materials is shown also in figure 8.

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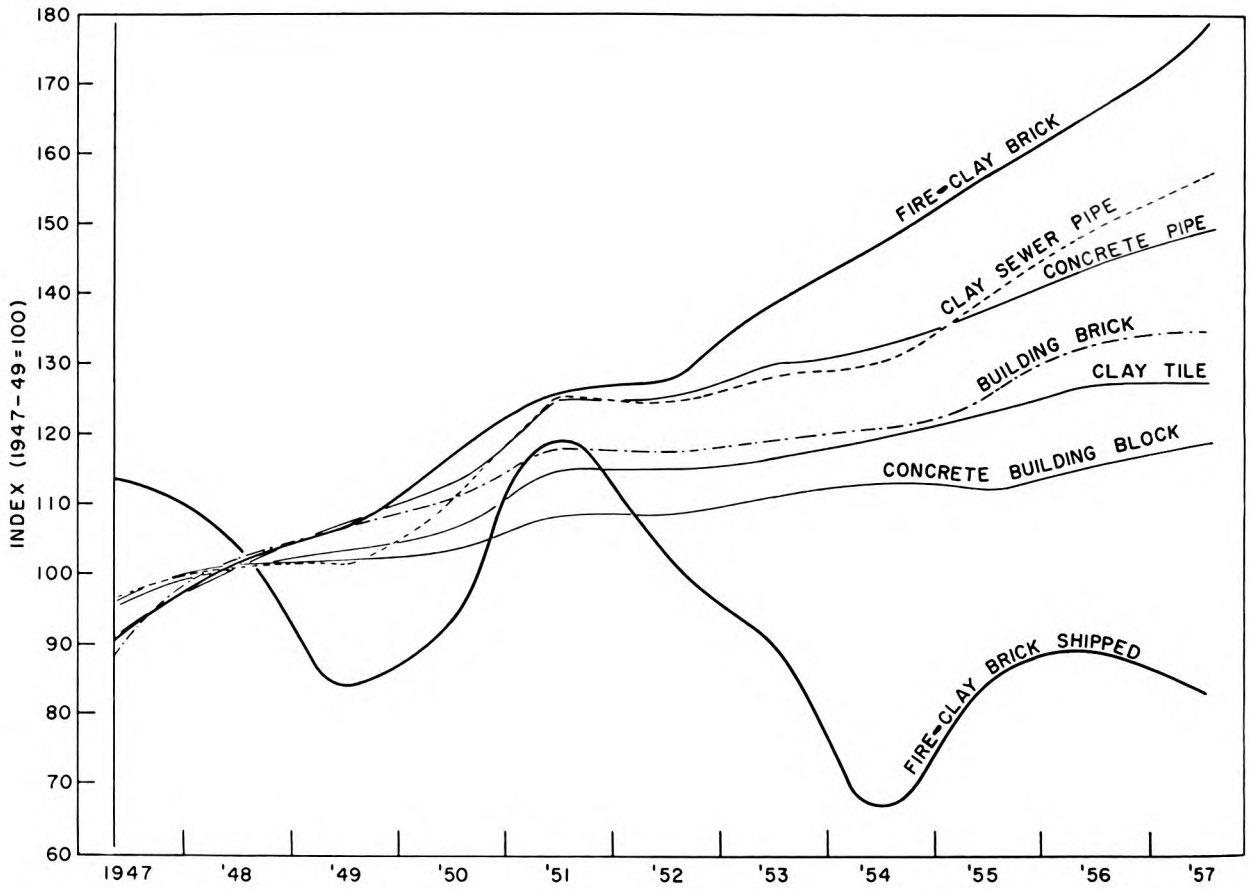


FIGURE 8. - Index of Structural Mineral Product Wholesale Price[1/] and of Quantities of Firebrick Shipped[2/], 1947-57.

1/ U. S. Department of Labor, Bureau of Labor Statistics, Division of Prices and Cost of Living.

2/ U. S. Department of Commerce, Bureau of Census, Industry Division.

Although the increase for clay refractories has risen substantially, the increase is not as great as that for nonclay refractories (table 22).

TABLE 22. - Index of average values for clay and nonclay refractories[1/]

(1947-49 = 100)

| Year | Clay refractories index | Nonclay refractories index | Year | Clay refractories index | Nonclay refractories index |
|---|---|---|---|---|---|
| 1947..... | 84 | 90 | 1953..... | 145 | 157 |
| 1948..... | 105 | 102 | 1954..... | 153 | 163 |
| 1949..... | 111 | 108 | 1955..... | 155 | 169 |
| 1950..... | 119 | 120 | 1956..... | 171 | 190 |
| 1951..... | 131 | 136 | 1957..... | 190 | 209 |
| 1952..... | 137 | 141 | | | |

1/ Index compiled by author. Clay refractory values based on average values of firebrick, superduty brick, high-alumina brick, ladle brick, and insulating brick. Nonclay values were established from magnesite, chrome, and silica refractory values.

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## ESTIMATED FUTURE REQUIREMENTS

It is estimated that since 1930 refractory production has been increasing at a rate of 2.8 percent per year. This rate of increase is only slightly less than the growth of gross national product. In the projections shown in figure 9 the output of clay refractories was calculated to be increasing at a rate of 1.5 percent per year. Silica refractory production was extrapolated at a rate of 3.0 percent per year. Basic refractories production increased at a rate of 9.8 percent per year since 1930; however, for the purpose of projection, the 6.0-percent increase prevalent since 1947 was used. In the 18 years between 1957 and 1975 refractory production will increase 64 percent. Silica refractories will increase an estimated 70 percent, fireclay refractories, 31 percent, and basic refractories, 185 percent.

The competition between clay and nonclay refractories is not entirely direct. There are uses for which each is particularly suited. For some uses, basic brick have replaced clay refractories. There has been a growing use in the production of nonclay refractories, so at the present time the value of nonclay refractories exceeds that of clay refractories (table 23).

The price spread between basic and clay refractories may reverse the trends in substitution in competitive uses and require revisions in the estimated future requirements of each. The lower rate of growth of clay refractories is attributed to longer refractory life because of greater quality of the product, as well as to substitution.

TABLE 23. - Value of shipments of clay and nonclay refractories in the United States, 1946-57[1/]

(million dollars)

| Year | Clay refractories | Nonclay refractories | Total |
|---|---|---|---|
| 1946..... | 153.3 | 71.8 | 225.1 |
| 1947..... | 110.9 | 93.3 | 204.2 |
| 1948..... | 119.4 | 94.4 | 213.8 |
| 1949..... | 102.1 | 82.0 | 184.1 |
| 1950..... | 126.7 | 112.0 | 238.7 |
| 1951..... | 171.1 | 155.8 | 326.9 |
| 1952..... | 161.1 | 139.2 | 300.3 |
| 1953..... | 159.7 | 164.7 | 324.4 |
| 1954..... | 129.1 | 2/127.6 | 2/256.7 |
| 1955..... | 181.1 | 187.4 | 368.5 |
| 1956..... | 208.6 | 210.1 | 418.7 |
| 1957..... | 208.3 | 253.1 | 461.4 |

1/ U.S. Bureau of the Census, Facts for Industry--Refractories, 1946-57.

2/ Does not include shipments of ground crude fire clay, high-alumina clay, or silica fire clay.

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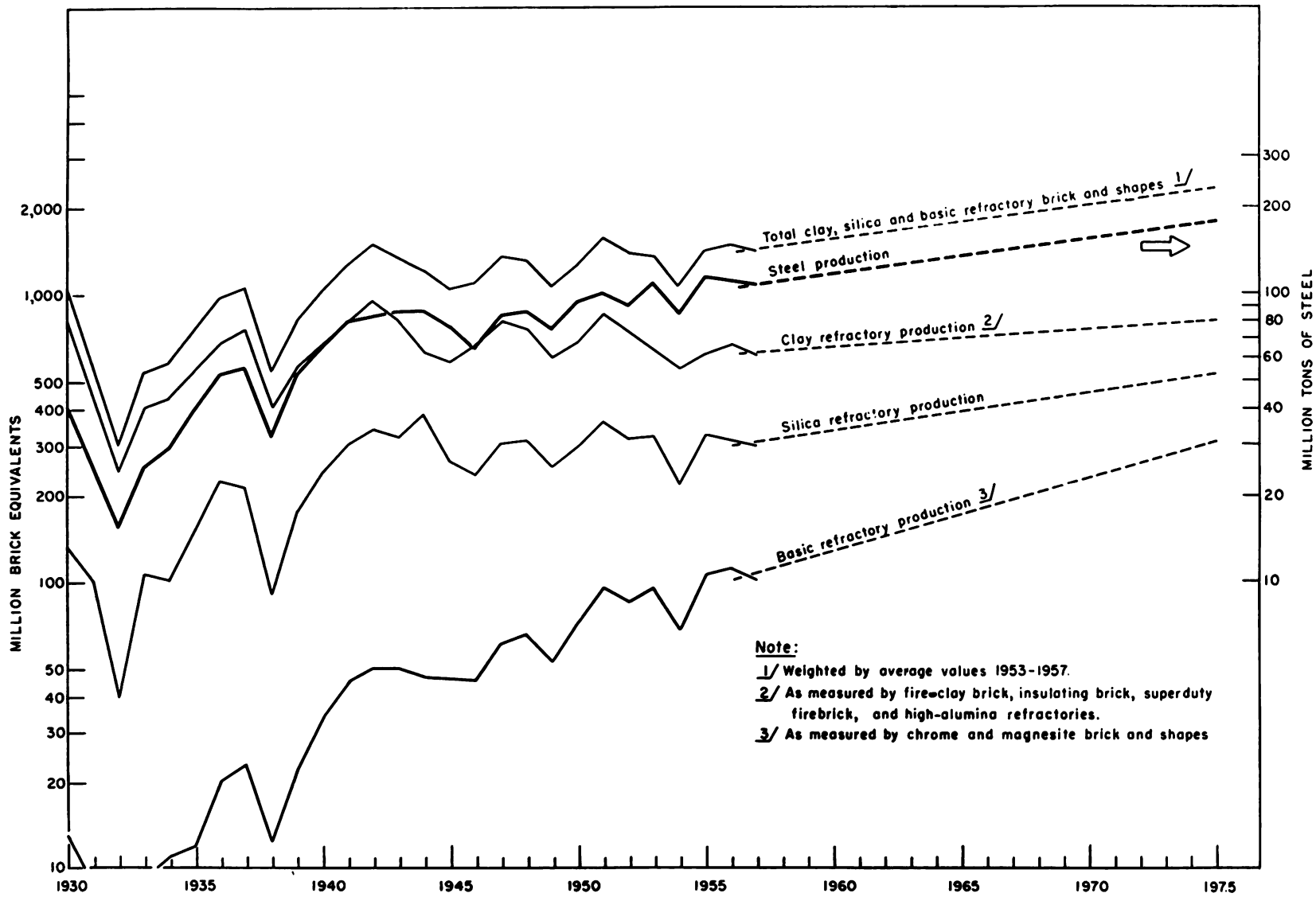


FIGURE 9. - Production of Steel and Clay, Silica and Basic Refractories, 1930-57, With Projections to 1975.

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It is estimated that by 1975, 8.1 million tons of fire clay will be required annually by refractories plants in the United States. Missouri is expected to increase its share of the total supply to 32 percent of refractory clay produced (fig. 10).

Clays vary so much in chemical and physical characteristics, even within the class, that estimating requirements by type of clay is difficult. Approximately 57 percent of all clays used in Missouri for manufacturing refractories are plastic or semiflint clays. Flint clays represent another 30 percent, and burley, burley-flint, and diaspore comprise an additional 10 percent. The remaining 3 percent is bauxite.

Further development in the Southwest and other States where Missouri has a competitive freight advantage will potentially increase these requirements for Missouri clays. Because Missouri has been furnishing such a large part of the superduty refractories requirements of the United States, these additional requirements may drain the already depleting supplies of flint fire clays. In considering long-term demand for superduty and high-alumina refractories--for which products high-grade Missouri hard flints have been requisite--increasing the supplies of these clays or finding suitable substitutes is a crucial factor.

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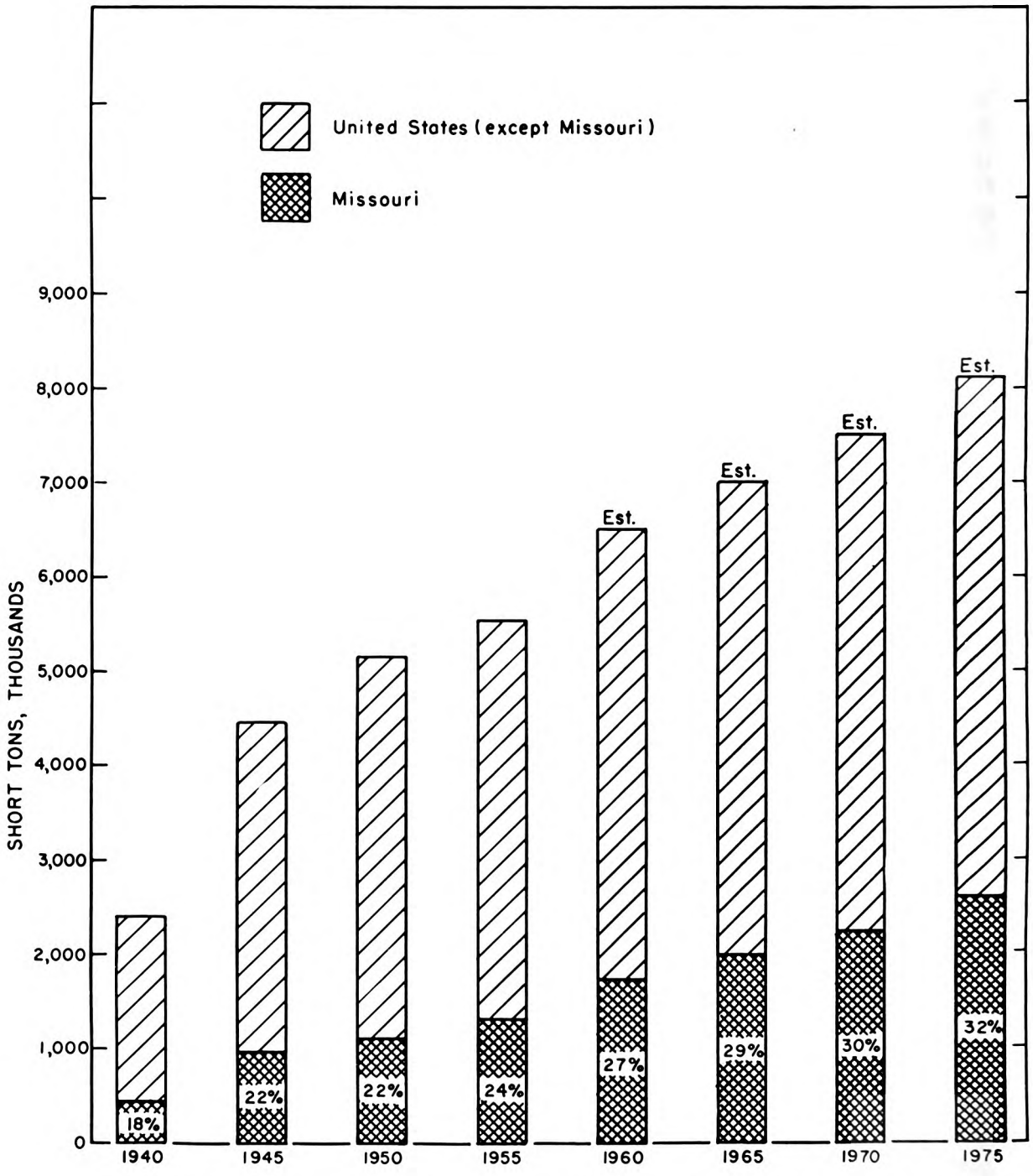


FIGURE 10. - Demand for Refractory Fire Clays Produced in Missouri and in the United States, 1940-75.

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# APPENDIX I

## Competence of Data in Report

Statistical data on the quantity and value of refractories production and shipments have been published since 1946 by the Bureau of the Census in the series entitled Facts for Industry--Refractories. These data make a comprehensive breakdown of national production and shipments by type of refractory. No data are available on consumption or shipments of refractories to specific geographical areas or to types of consumers. An occasional informal estimate of refractories consumption by industry groups has been published. Further statistical data on production of refractory materials have been published by the Bureau of Mines. Generally, however, data on the refractories industry and markets are scarce.

The main statistical contributions of this study are:

1. Estimates of the value of refractories consumed in the States in the South Central United States.

2. Estimates of consumption by industry groups.

3. Estimates of consumption by type of refractory.

4. Mine productivity of the refractories industry of Missouri.

5. Destination of shipments of refractories produced in Missouri.

6. Origin of refractories consumed in the South Central United States.

7. Comparative freight rates.

The main analytical contributions of the study are:

1. An analysis of the competitive position of the Missouri refractories industry.

2. An estimate of raw-material requirements for refractories.

3. Mining and refractories production practices in Missouri.

4. Growth of the market for refractories in the South Central United States.

A major omission of the study was a detailed study of the costs of mining and transporting refractory raw materials. An accurate study would be useful in evaluating a probable cost range for beneficiation of submarginal raw materials.

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## APPENDIX II

### Glossary

Ball clay: A highly plastic refractory bond clay of very fine grain, often high in carbonaceous matter, which fires to a light color.

Basic refractories: Refractories whose major constituent is lime, magnesia, chromite, spinel, or forsterite. Chromite, when used alone, is a neutral refractory.

Burley clay: A fire clay containing aluminous or ferruginous burls or nodules.

Castable refractories: Mixtures of heat-resistant aggregate and heat-resistant hydraulic cement; for use they are mixed with water and rammed or poured into place.

Dead-burned dolomite: Dolomite that has been calcined until it is volume-constant, compact, and hard.

Diaspore clay: A rock consisting essentially of the highly aluminous mineral diaspore bonded by fire clay.

Flint fire clay: A hard fire clay with little or no plasticity, which usually breaks with a conchoidal fracture.

Grog: Burned refractory material, usually calcined clay or crushed brick, added to brick or mortar mix to reduce shrinkage in drying and firing.

Novaculite: An extremely fine-grained quartzose rock of sedimentary origin.

Periclase: A mineralogical designation for crystalline magnesium oxide obtained commercially by sintering magnesias containing a minimum of 90 percent MgO.

Plastic clay: A fire clay with sufficient natural plasticity to bond non-plastic materials.

Pyrometric-cone equivalent (P.C.E.): The refractoriness of a material, expressed in terms of standard pyrometric cones.

Ramming mixes (plastic refractories): A blend of ground fire clays in plastic form suitable for ramming into place to form monolithic linings.

Refractoriness: In ceramics, the property of resistance to melting, softening, or deformation at high temperatures.

Silica refractories: Fired refractories consisting essentially of silica and usually made from quartzite bonded with 1.8 to 3.5 percent of added lime.

Tabular alumina: Aluminum oxide converted to the corundum form by heating to temperatures slightly below the fusion point of aluminum oxide. The term tabular refers to flat crystal facets visible in rough broken particles.

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## APPENDIX III

### Production and Consumption of Refractories by the Horizontal-Retort Zinc Industry in Arkansas, Oklahoma, and Texas

About $2 million worth of condensers and retorts is produced and consumed each year by the horizontal-retort zinc industry of Arkansas, Oklahoma, and Texas. In the production of these products the industry uses approximately 30,000 tons of plastic fire clay valued at $75,000 and 10,000 tons of calcined flint and adobe valued at $200,000. About 160 men are employed in zinc-industry potteries in the 6 plants in Arkansas, Oklahoma, and Texas. These potteries produce retorts, condensers, and some firebrick and special shapes for use in the zinc plants.

In 1954 an estimated $50,000 worth of high-heat duty and superduty brick was purchased by this industry from refractories companies for minor repairs of furnaces and kilns. In addition, far larger purchases are required from time to time for major furnace and kiln construction.

The reported average life of retorts was 50 days; that of condensers, 6 days. For each ton of sinter processed, about 0.53 retort and 4.5 condensers were used.

The following is an approximate analysis of the clays used for retorts:

| | Percent |
|---|---|
| $SiO_2$ | 56.0 |
| $Al_2O_3$ | 30.0 |
| $Fe_2O_3$ | 2.5 |
| CaO | .5 |
| MgO | .1 |
| Ignition loss | 10.0 |

The reporting companies used retorts and condensers made from clays from Monroe and St. Louis Counties, Mo. The choice of these clays was the result of extensive tests by different users. For some time, a Cheltenham clay mined near St. Louis was used widely by the retort zinc industry, but the deposit was exhausted. It was reported that it was difficult to find another clay suitable for retorts and condensers.

Research still is being directed toward improving retort and condenser life. Two companies felt that a clay having a higher alumina content would improve condenser life. One company is considering the blending of Kentucky, Tennessee, and Mississippi clays to get the right combination of alumina and silica. In retorts, a high silica content is important to give necessary structural strength at higher temperatures. Higher alumina clays have a tendency to sag in the middle of the retort at higher temperatures.

Condensers are made of approximately 50 percent clay and 50 percent retort grog. Retorts usually are made of about 50 percent raw clay, 25 percent silica flour, and 25 percent calcined flint. The calcined clay was purchased from Arkansas and Colorado.

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